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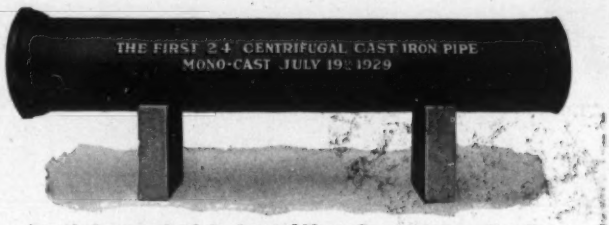

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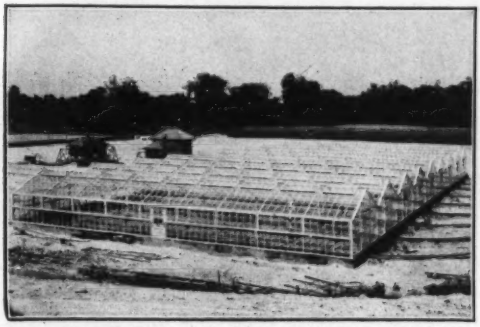

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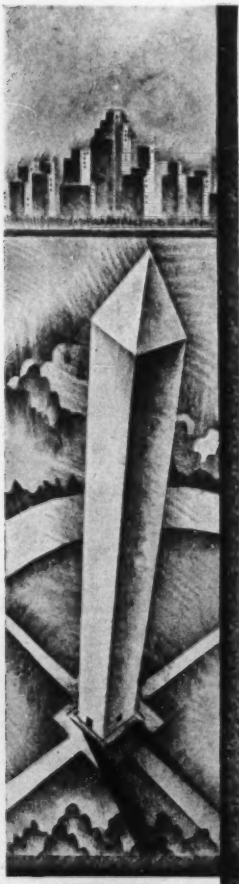

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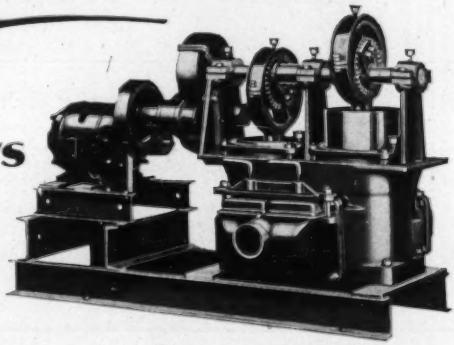

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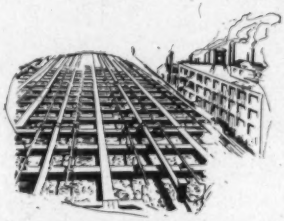

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Sewage Research

Thermophilic Digestion of Daily Charges of Fresh Solids and Activated Sludge*

By H. Heukelekian**

In two previous papers[2,4] certain conclusions were reached in regard to thermophilic digestion of fresh solids from a series of experiments conducted with the batch process. Fresh solids and ripe thermophilic sludge were mixed in a certain ratio and incubated at approximately 50° C. and the digestion time determined. It was found as a result of such studies that the digestion of properly seeded mixtures could be accomplished in 12 to 14 days. It was further observed that there was an initial lag of 5 to 6 days before rapid digestion was initiated. It was therefore to be expected that with daily additions when the maximum activity was established the digestion time could be reduced to 6 to 8 days. The purpose of the following studies was to determine whether a reduction of such or possibly greater magnitude in the digestion time could be effected.

Methods

In the bottom of two five-gallon carboys a hole was drilled and fitted with rubber stoppers with two holes. These carboys were inverted so that the necks of the bottles served as a hopper to collect the sludge. The two-holed stopper in the neck of the bottle was fitted with two glass tubes, one to remove the sludge from the bottom of the hopper or neck, the other to remove liquid half-way from the bottom. The flat top of the bottle served now as the top of the miniature digestion tank. One of the holes in the stopper in the top was connected with a gas collector and the other was fitted with a wide-stem funnel for the addition of solids. The top of the funnel was stoppered so as to prevent the escape of gas and the stem of the funnel had a wide glass tubing attached which reached below the surface of the liquid in the bottle.

Sludge was drawn by opening the outlet at the bottom. After the pre-determined quantity of sludge was drawn the outlet was closed. The stopper in the funnel was opened, a definite quantity of solids added and

* *Journal Series Paper of the New Jersey Agricultural Experiment Station, New Brunswick, N. J., Dept. Sewage Research.*

** *Research Bacteriologist, Dept. Sewage Research.*

the funnel stoppered again. The bottle was then shaken, whenever so desired, by giving it a rotary motion. Then the gas outlet was opened and the gas collected over water and measured. The volume of solids thus added varied usually from 500 cc. to 3000 cc. dependent on the concentration of the solids as well as the desired amount of dry solids to be added. Consequently the gas was produced in rather large quantities. Gas-saturated water or sodium-chloride water was not used and therefore the volume of the gas recorded is probably somewhat lower than the actual amount, due to the absorption of carbon dioxide. Since no gas analyses were made the effect on the volume of gas alone may be neglected.

The amount of sludge to be drawn each day was calculated from the rate of decomposition in the following manner. Certain basic figures were required which were as follows:

(1) The volume of gas produced per gram of volatile matter decomposed. For fresh solids this was taken as 1000 cc. and for activated sludge 700 cc., based on experimental evidence.

(2) Percentage decomposition of raw volatile matter added. For fresh solids, reduction of volatile matter was taken as 70 per cent and for activated sludge as 60 per cent, based on experimental evidence.

(3) It was assumed that there was a direct proportionality between gas production and digestion.

Example: Assume that at the end of the 11th day a total of 50,000 cc. of gas was produced from 100 grams of volatile matter added in the fresh solids. Complete decomposition would have produced 100,000 cc. of gas, therefore only 50 per cent of the total charge or 50 grams were actually decomposed at that date. From a charge of 50 grams of volatile matter in fresh solids 15 grams of ripe volatile matter would remain (70 per cent reduction). If up to that date 10 grams of volatile matter had been drawn, on that date 5 grams would remain to be drawn. Estimating the concentration of the solids, which after a little practice can be done fairly accurately, a certain volume is drawn. Daily removals are accumulated for a few days after which an analysis is made on the composite to determine whether too much or too little has been drawn, and subsequent withdrawals are made accordingly.

Fresh solids were obtained from Plainfield, New Jersey, by sinking pails in the sedimentation compartments of the Imhoff tanks. Activated sludge was obtained from the returned-sludge pipe of the activated sludge plant at Tenafly, New Jersey. After sedimentation, the supernatant liquor of the activated sludge was siphoned off in order to concentrate the solids. Sufficient quantities were collected at one time for a period of 5 to 7 days. When not in use these raw materials were stored in a refrigerator.

Records were kept of the volume of the daily charges and withdrawals as well as the solids and ash content.

The temperature of incubation was 50° C. in all experiments.

Results

1. Daily Additions of Fresh Solids with No Withdrawals.—To two portions of ripe thermophilic sludge, which had been standing idle for some time, daily additions of fresh solids were made. The two bottles A and B were run parallel in order to determine the degree of accuracy. The condensed results are given in Table I. The original ripe sludge in each bottle contained 68.5 grams of volatile matter. To this was added, in 10

TABLE I

THERMOPHILIC DIGESTION WITH DAILY ADDITIONS OF FRESH SOLIDS (A AND B ARE DUPLICATES)

	A	B
Original ripe sludge (grams volatile matter)	68.5	68.5
Total charge of fresh solids (grams volatile matter) (10 days)	105.4	105.4
Daily average of fresh solids (grams volatile matter)	10.5	10.5
Daily charge, per cent of the original ripe sludge	15.3	15.3
Total gas, cc. (27 days)	62,200	60,800
Gas yield per gram raw volatile matter added	610	580
Gas produced at end of charging period, per cent of total	24	24
Variability in gas yield (per cent of average)	+0.8	−1.1

days, 105.4 grams of volatile matter in fresh solids, or an average daily charge of 15.3 per cent of the original sludge. A total of 62,200 cc. and 60,800 cc. of gas was produced from A and B, respectively, in 27 days, or 610 and 580 cc. per gram of volatile matter added. At the end of the charging period only 24 per cent of the total potential gas was produced from each. Since the original ripe sludge was not actively decomposing, the digestion proceeded slowly. At the end of 27 days the digestion was not complete as is indicated by the low gas yield. The variation from the average total yield of gas was, for A, 0.8 per cent, and for B, 1.7 per cent.

2. Daily Additions of Fresh Solids and Withdrawals of Ripe Sludge.—The ripe sludge from the previous experiments was divided into two portions, each containing 130 grams of volatile matter, and placed in bottles A and B, which were kept under identical conditions. Daily charges of fresh solids were made for 12 days, each totaling 97 grams of volatile matter, or 6.1 per cent on the basis of volatile matter in the original sludge (Table II). The sludge withdrawn contained 35.4 and 39.5 grams of volatile matter, from A and B, respectively. The decomposition of 97 grams of volatile matter should yield 29.0 grams in the ripe sludge, assuming 70 per cent decomposition of the added solids. Therefore the withdrawals were somewhat more than sufficient to account for the theoretical amount

of sludge produced. The total gas production for the period of 25 days of digestion was 94,200 and 90,900 cc. from A and B, respectively, or per gram of raw volatile matter a yield of 970 and 935 cc., respectively. The gas produced at the end of the charging period was 58 and 52.5 per cent of the total. The variation from the average total gas yield was for A, 1.8, and for B, 1.7 per cent.

TABLE II

THERMOPHILIC DIGESTION WITH DAILY ADDITIONS OF FRESH SOLIDS AND WITHDRAWALS (A AND B ARE DUPLICATES)

	A	B
Original ripe sludge (grams volatile matter)	130	130
Total charge of fresh solids (grams volatile matter) (12 days)	97	97
Daily average charge of fresh solids (grams volatile matter)	8.1	8.1
Daily charge per cent of the original ripe sludge	6.1	6.1
Sludge withdrawal (grams volatile matter)	35.4	39.5
Total gas, cc. (25 days)	94,200	90,900
Gas yield per gram raw volatile matter added, cc.	970	935
Gas produced at end of charging period, per cent of total	58	52.5
Per cent ash in the sludge withdrawn (minimum and maximum)	44.6–56.2	47.0–57.6
Per cent ash in fresh solids (minimum and maximum)	21.7–23.0	21.7–23.0
Variability in gas yield (per cent of total average)	+1.8	−1.7

With a somewhat smaller daily charge and with a more active thermophilic sludge than in the first experiment, the rate of decomposition was hastened, so that the yield of gas when the daily charges were discontinued was 52–58 per cent of the total possible gas yield. Considerable amounts of sludge were withdrawn in the meantime, although not quite equal to estimates of the theoretical amount of sludge produced. The yield of gas was higher in the second experiment than in the first because the ripe sludge contained some undigested material from the previous experiment.

The variability in the total gas yield of the two experiments would indicate that the experimental error is small and there is no necessity in running the experiment in duplicate.

3. Daily Additions of Fresh Solids with and without Shaking.—The ripe sludge from the previous experiment was mixed and re-distributed into bottles A and B, the first receiving 101 grams of volatile matter and the second 98 grams. There was a lapse of one day between the two experiments. The results are given in Table III. Daily addition of fresh solids to each bottle amounted to 112.7 grams volatile matter. This was distributed over 13 days or an average daily charge of 8.7 per cent of the original ripe sludge. After each addition bottle B was shaken with a rotary motion while A was allowed to stand undisturbed. No ripe sludge was withdrawn in the experiment.

The unshaken bottle produced a total of 87,080 cc. gas in 22 days or 775 cc. per gram of raw volatile matter added. The bottle which was shaken produced 95,360 cc. of gas or 845 cc. per gram of raw volatile matter. The gas produced at the end of the charging period was 57.5 and 78.5 per cent of the total gas yield, for A and B, respectively.

TABLE III

THERMOPHILIC DIGESTION OF FRESH SOLIDS WITH DAILY ADDITIONS

	A Not Shaken	B Shaken
Original ripe sludge (grams volatile matter)	101.2	98.5
Total charge of fresh solids in 13 days (grams volatile matter)	112.7	112.7
Daily average charge of fresh solid (grams volatile matter)	8.7	8.7
Daily charge, per cent of the original ripe sludge	8.5	8.8
Total gas (22 days)	87,080	95,360
Gas yield per gram of raw volatile matter	775	845
Gas produced at end of charging period, per cent of total	57.5	78.5
Per cent ash in original sludge	41.2	41.2
Per cent ash in final sludge	42.2	42.6
Per cent ash in fresh solids (minimum and maximum)	21.4–23.6	21.4–23.6

Figure 1 represents graphically the daily gas production for the two bottles. The gas production in both of them rose in 6 days to a maximum, which was maintained as long as the daily charges were added. The shaken bottle maintained a higher peak than the unshaken. When

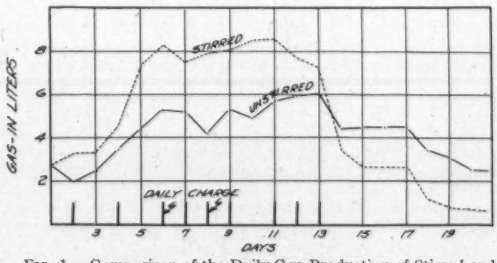

FIG. 1.—Comparison of the Daily Gas Production of Stirred and Unstirred Sludges Receiving Daily Charges of Fresh Solids under Thermophilic Conditions.

the charges were stopped at the end of 13 days the gas production decreased more sharply in the shaken than the unshaken bottle.

With 8.7 per cent daily addition of raw material (on volatile matter basis) 510 cc. of gas was produced at the end of the charging period. However, with a similar charge when the bottle was shaken, 710 cc. of gas was produced during the same period, an increase of 39.3 per cent due to shak-

ing. The shaking was only once a day and it might be possible that with continuous or more frequent shaking better results could have been obtained. It should be borne in mind also that the percentage of gas produced at the end of the charging period is necessarily low because of the initial 5 to 6 days during which gas production was reaching a maximum. If the initial period was discarded or the charging continued over a longer period the percentages would be higher. On the other hand no sludge was withdrawn and the seeding was accordingly increased during the digestion, which might have tended to give a better digestion than would have been the case if ripe sludge had been withdrawn. However, once the peak of gasification was attained there was apparently no further marked improvement during the course of digestion with the shaken bottle while gas production in the unshaken bottle showed a slow and gradual tendency to increase. The final sludge had as high an ash content as the original. In order therefore to determine the rate of digestion the above experiment was repeated with the modification of withdrawing sludge.

4. Daily Additions and Withdrawals with and without Shaking.—The thermophilic sludge from the previous experiment was mixed and distributed into bottles A and B, each of which received 115 grams of volatile matter in the ripe sludge. The total charge of fresh solids to these bottles in 11 days was 211 grams of volatile matter or a daily average charge of 16.2 per cent of the original ripe sludge, as represented in Table IV.

TABLE IV

DAILY FRESH SOLIDS ADDITIONS AND WITHDRAWALS OF RIPE SLUDGE WITH AND WITHOUT SHAKING

	A Shaken	B Not Shaken
Original ripe sludge (grams volatile matter)	115	115
Total charge of fresh solids (11 days) (grams volatile matter)	211	211
Daily average charge of fresh solids (grams volatile matter)	19.2	19.2
Daily charge, per cent of the original ripe sludge	16.2	16.2
Sludge withdrawn (grams volatile matter)	96.2	59.4
Total gas, cc.	184,800	147,600
Gas yield per gram raw volatile matter added, cc.	875	700
Gas produced at end of charging period, per cent of total	68	53.0
Sludge added + original sludge (grams volatile matter)	326	326
Sludge withdrawn + sludge at end (grams volatile matter)	165	176.4
Sludge decomposed (grams volatile matter)	161	149.6
Percentage volatile matter added decomposed	76	71
Percentage total volatile matter decomposed	49.5	46.0
Percentage ash in original ripe sludge	43.0	43.0
Percentage ash in sludge withdrawn (minimum and maximum)	42.5–49.0	43.5–47.8
Percentage ash in final sludge	43.0	42.7
Percentage ash in fresh solids (minimum and maximum)	25.5–28.0	25.5–28.0

Bottle A was shaken every day after the addition of fresh solids and B was left undisturbed. Sludge was drawn before the addition of fresh solids, which for the entire period amounted to 96.2 grams and 59.4 grams of volatile matter for A and B, respectively. The shaken bottle produced 184.8 liters and the unshaken 147.6 liters of gas. The gas yield per gram of raw volatile matter added was 875 and 700 cc., respectively. Gas produced at the end of charging period was 595 cc. for the shaken and 370 cc. for the unshaken bottle per gram of volatile matter added or an acceleration of 60 per cent due to shaking. Of the added sludge 76 and 71 per cent and of the total sludge 49.5 and 46.0 per cent was decomposed at the end of incubation.

Of the total charge of 211 grams of volatile matter 24 per cent, or 51 grams, remained in the shaken bottle as sludge; against this 96 grams was

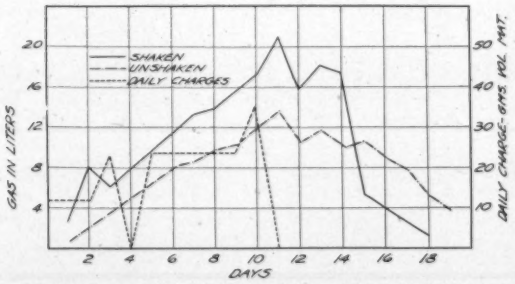

FIG. 2.—Comparison of the Daily Gas Production of Stirred and Unstirred Sludges Receiving Daily Charges of Fresh Solids under Thermophilic Conditions.

withdrawn. In the unshaken bottle the theoretical amount of sludge formed was 61 grams and 59.5 grams was withdrawn. Thus the shaken bottle had actually less sludge left than the unshaken and therefore had less seeding material. In spite of this deficiency a greater percentage of the total gas was produced at the end of the charging in the shaken than in the unshaken bottle. The acceleration in gas production due to shaking was 28 per cent. With daily average charges of 16.2 per cent of the original amount of sludge, digestion proceeded satisfactorily in both the bottles, but somewhat better in the shaken than in the unshaken. The total yield of gas per gram of raw volatile matter was greater in the shaken than in the unshaken, probably due to the fact that the sludge in the unshaken bottle had not reached the same stage of decomposition at the end of the experiment as that in the shaken bottle. The sludge with-

drawn and the sludge at the end had as high an ash content as the original sludge.

Figure 2 represents the total daily gas production from the sludge in the shaken and unshaken bottles, as well as the daily charges. The gas production increased gradually up to the 11th day of digestion, when the peak was reached in both bottles. The shaken bottle maintained a higher gas production, with the exception of the last few days of digestion when the charges had been discontinued. The peak of gas production on the 11th day was due to the larger charge on the previous day. It would seem, therefore, that the maximum rate of decomposition had been reached by the 10th day, after which the charges were discontinued. Three days after the charges were discontinued gas production in the shaken bottle decreased sharply while the decrease in the unshaken bottle was more uniform and prolonged, indicating again that more of the charge had been left undecomposed in the unshaken bottle at the end of charging.

TABLE V

DAILY ADDITIONS OF FRESH SOLIDS AND ACTIVATED SLUDGE WITH WITHDRAWALS OF SLUDGE

	A Activated Sludge	B Fresh Solids
Original ripe sludge (grams volatile matter)	78	78
Total charge of raw solids in 7 days (grams volatile matter)	85.0	89.7
Daily average charge of solids (grams volatile matter)	12.1	12.8
Daily charge per cent of the original ripe sludge	15.5	16.4
Sludge withdrawn (grams volatile matter)	5.5	7.4
Total gas, cc.	36,700	61,900
Gas yield, cc. per gram raw volatile matter added	430	690
Gas per gram volatile matter decomposed	710	1000
Gas produced at end of charging period, per cent of total	76.0	80.0
Sludge added + original sludge (grams volatile matter)	163	167.7
Sludge withdrawn + sludge at end (grams volatile matter)	111.5	107.4
Sludge decomposed (grams volatile matter)	51.5	60.3
Per cent volatile matter added decomposed	60.5	66.2
Per cent total volatile matter decomposed	31.6	36.0
Per cent ash in original sludge	45.3	45.3
Per cent ash in sludge withdrawn	59.0	51.0
Per cent ash in final sludge	46.2	43.6
Per cent ash in raw materials added (minimum and maximum)	31.9–33.3	22.4–23.0

5. Daily Additions of Fresh Solids and Activated Sludge and Withdrawals of Ripe Sludge.—Within a period of 7 days 85 grams of activated sludge and 89.7 grams of fresh solids were added to 78 grams of ripe thermophilic sludge obtained from the previous experiment. (Table V) On two of these 7 days nothing was added, so that the charging period was actually only 5 days. On the basis of a 7-day charging period the daily charges amounted to 15.5 and 16.4 per cent of the original ripe sludge, for the

activated sludge and fresh solids, respectively. The amount of sludge withdrawn was comparatively small. Both carboys were shaken similarly each day after the addition of the raw material. The gas yield per gram of raw volatile matter added was 430 grams from activated sludge and 690 grams from fresh solids. The gas produced at the end of the charging period was 76 and 80 per cent of the total, for activated sludge and fresh solids, respectively. In the digestion of activated sludge 60 per cent of the volatile matter added and 31.6 per cent of the total volatile matter was decomposed. In the digestion of fresh solids 66.2 per cent of the volatile matter added and 36.0 per cent of the total volatile

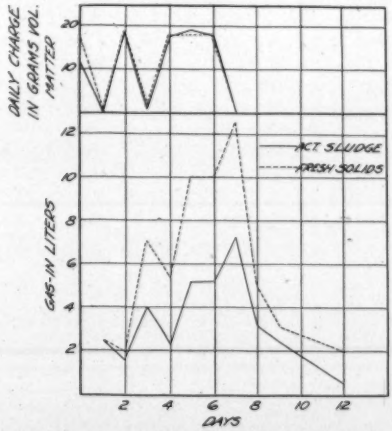

FIG. 3.—Comparison of the Daily Gas Production from Activated Sludge and Fresh Solids and the Daily Charges.

matter was decomposed. The amount of gas per gram of volatile matter decomposed was for the activated 710 cc. and for the fresh solids 1000 cc.

Figure 3 represents the daily gas production and the charges for the activated sludge and fresh solids. Gas production in both mixtures rose to a peak on the 7th day, when the charges were stopped. Thereafter the gas production decreased rapidly. On two occasions during the charging period when no solids were added, the next day gas production decreased. It is also of interest to note that when the charges were stopped altogether gas production dropped suddenly. Considering the fact that 76 to 80 per cent of the total gas was produced at the end of the

charging this is not surprising. This rapid decomposition took place with daily additions of 15 to 16 per cent on the basis of volatile matter. Not sufficient sludge was withdrawn, however, to maintain the original ratio.

The gas yield, as shown in Table V, was higher for fresh solids than for activated sludge. Activated sludge yielded 38 per cent less gas than fresh solids. This difference has been noted before with low temperature digestion. The percentage of volatile matter decomposed was also somewhat lower for activated sludge than for fresh solids. The ash contents in the sludge withdrawn and the final sludge indicate that the sludge was fully decomposed.

6. Daily Additions of Activated Sludge and Fresh Solids and Withdrawals of Ripe Sludge.—The experiment was repeated in essentially the same way. Bottle A, with 77.5 grams of ripe volatile matter in the thermophilic sludge, received 162.5 grams activated sludge in 9 days, or a daily average charge of 23.2 per cent of the original ripe sludge. Bottle B, with a similar initial content of ripe sludge, received 155.8 grams of fresh solids, or a daily load of 22.3 per cent of the original ripe sludge (Table VI). Both bottles were shaken every day in the usual manner. Sludge withdrawn throughout the charging period amounted to 25.0 grams of volatile matter in each case. The gas yield per gram of volatile matter added was 385 cc. for activated sludge and 770 cc. for fresh solids, or 605

TABLE VI

DAILY ADDITIONS OF FRESH SOLIDS AND ACTIVATED SLUDGE AND WITHDRAWALS OF RIPE SLUDGE

	A Activated Sludge	B Fresh Solids
Original ripe sludge (grams volatile matter)	77.5	77.5
Total charge of raw solids 9 days (grams volatile matter)	162.4	155.8
Daily average charge of solids (grams volatile matter)	18.0	17.3
Sludge withdrawn (grams volatile matter)	25.0	25.0
Daily charge, per cent of the original ripe sludge	23.2	22.3
Total gas, cc.	62,250	119,700
Gas yield per gram raw volatile matter added	385	770
Gas per gram volatile matter decomposed	605	950
Gas produced at end of charging period, per cent of total	84.0	89.0
Sludge added + original sludge (grams volatile matter)	240	233.3
Sludge withdrawn + sludge at end (grams volatile matter)	137.0	107.5
Sludge decomposed (grams volatile matter)	103	125.8
Per cent volatile matter added decomposed	63.4	81.0
Per cent total volatile matter decomposed	42.8	54.0
Per cent ash in the ripe sludge withdrawn (minimum and maximum)	53.8–56.5	51.4–52.0
Per cent ash in the ripe sludge at the beginning	44.3	44.3
Per cent ash in the ripe sludge at the end	47.0	45.6
Per cent ash in the raw materials added	34.0	28.0

and 950 cc., respectively, per gram of volatile matter decomposed. At the end of the charging period 84 and 89 per cent of the charge had been decomposed, as indicated by the percentage of gas yield at that time to the total gas yield. The decomposition of activated sludge resulted in 63.4 per cent reduction of the volatile matter added and 42.8 per cent reduction of the total volatile matter. The decomposition of fresh solids resulted in 81 per cent reduction of volatile matter added and 54.0 per cent of the total volatile matter in the mixture.

The decomposition of 162.4 grams of volatile matter in activated sludge

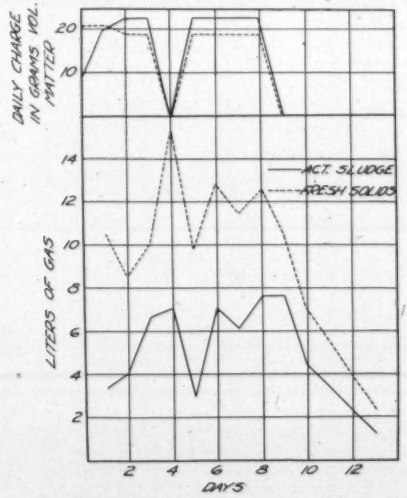

FIG. 4.—Comparison of the Daily Gas Production from Activated Sludge and Fresh Solids and the Daily Charges.

would produce a residue containing 59.0 grams of volatile matter. Only 25 grams of volatile matter was withdrawn in the ripe sludge. The decomposition of 155.8 grams of volatile matter in fresh solids would yield 29.6 grams volatile matter, of which 25.0 grams was actually withdrawn as ripe sludge. Not enough sludge was withdrawn from the activated-sludge mixture while nearly the theoretical amount was drawn from the fresh solids mixture.

With as high as 22 to 23 per cent daily additions of volatile matter

84 to 89 per cent of the total gas was produced at the end of the charging period. Activated sludge decomposed as rapidly as fresh solids but yielded 37 per cent less gas than fresh solids per gram of raw volatile matter.

To indicate that the decomposition was progressing satisfactorily, the percentage ash of the sludge withdrawn, of the sludge at the end and the beginning, and of the raw materials added are included in Table VI. The original ripe sludge contained 44.3 per cent ash, the activated sludge 34 per cent and the fresh solids 28 per cent The ripe sludge withdrawn and the sludge at the end had a somewhat higher ash content than the original sludge.

In Figure 4 is represented the daily gas production during the digestion of activated sludge and fresh solids as well as the daily charges. There was a sharp depression in the gas production on the 5th day in both mixtures; no charges were made on the previous day. Gas production increased again the following day and remained constant as long as the daily charges were continued. When these were discontinued the gas production decreased sharply in both mixtures.

7. Daily Additions of Fresh Solids and Activated Sludge with Withdrawals of Ripe Sludge.—In the final experiment the total charging period was 22 days, on 6 days of which no additions were made. The total additions were 509.2 grams volatile matter in the activated sludge and 516.9 grams volatile matter in fresh solids (Table VII). These were

TABLE VII

DAILY ADDITIONS OF ACTIVATED SLUDGE AND FRESH SOLIDS AND WITHDRAWALS OF RIPE SLUDGE

	A Activated Sludge	B Fresh Solids
Original ripe sludge (grams volatile matter)	49.0	49.0
Total charge of raw solids in 22 days (grams volatile matter)	509.2	516.9
Daily average charge (grams volatile matter)	23.1	23.5
Daily charge—per cent of the original ripe sludge	47.2	48.0
Sludge withdrawn (grams volatile matter)	170.6	81.7
Total gas, liters	200.6	336.2
Gas yield per gram raw volatile matter added	405	650
Gas yield per gram volatile matter decomposed	765	890
Gas produced at end of charging period, per cent of total	92.2	88.5
Sludge added + original sludge (grams volatile matter)	558.2	565.9
Sludge withdrawn + sludge at end (grams volatile matter)	288.6	186.9
Sludge decomposed (grams volatile matter)	269.6	379.2
Per cent volatile matter added decomposed	53.0	73.3
Per cent total volatile matter decomposed	48.3	67.7
Per cent ash in original ripe sludge	47.5	47.5
Average ash in raw materials added	37.0	23.4
Average ash in ripe sludge withdrawn	46.0	47.0
Average ash in ripe sludge at end	52.7	41.7

added originally to 49.0 grams of thermophilic ripe sludge, consequently the daily charges constituted 47 to 48 per cent of the original ripe sludge. Since 53 per cent of the volatile matter added in the activated sludge was decomposed, the amount of sludge formed from the total charge would be 240 grams. Of this only 170 grams were actually removed. In the fresh solids 73.0 per cent of the added volatile matter decomposed resulting in the formation of 140 grams of volatile matter in the ripe sludge. Of this 82.0 grams were actually removed.

The gas yield per gram of volatile matter was higher in the fresh solids

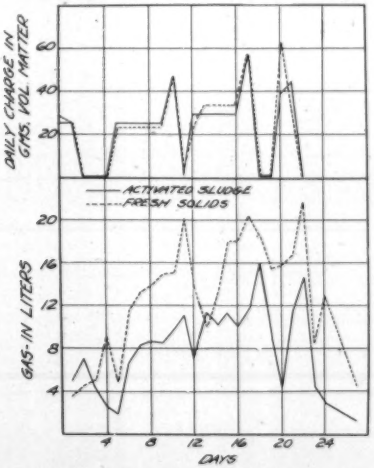

FIG. 5.—Comparison of the Daily Gas Production from Activated Sludge and Fresh Solids and the Daily Charges.

(650 cc.) than in the activated sludge (405 cc.). The gas produced at the end of the charging period was 92.2 per cent of the total for the activated sludge and 88.5 per cent for the fresh solids. Thus, over a somewhat longer period, the percentage of the charge decomposed at the end of the charging period was higher than when the period of charging was shorter. Furthermore, this high rate of decomposition took place with as much as 47 to 48 per cent daily loadings, on the basis of volatile matter. In spite of this high rate of loading, the ash contents of the sludge withdrawn and of the final sludge were high.

Figure 5 represents the daily gas production and the daily charges. It is apparent that the charges and gas production follow each other very closely. When no additions are made one day gas production drops very materially the next day and increases again when the additions are resumed.

The following table gives the 24-hour biochemical oxygen demand of the sludge drawn on one occasion during the progress of digestion:

	Activated Sludge	Fresh Solids
24-hour B. O. D., p. p. m.	2000	3025
Volatile matter, per cent	1.70	2.07
B. O. D./per cent vol. mat., p. p. m.	1180	1470
pH	7.8	8.1

As has been pointed out by Rudolfs and Fischer,[3] a well digested sludge, stable enough to be drawn, should have a B. O. D. not more than 1500 p. p. m. for each per cent organic matter. Both from the standpoint of B. O. D. and pH the sludge would be considered ready to be drawn, and as has been pointed out before, the ash content was steadily high. The sludge had a black color and an inoffensive cooked odor.

Discussion

In Table VIII are summarized some of the salient results from all the experiments reported above.

In the first experiment, when only 6 to 8 per cent of the original vola-

TABLE VIII

SUMMARY OF RESULTS OF ALL EXPERIMENTS

Expt.	Average Daily Charge			Gas Yield			Gas at End of Charging Period			Volatile Matter Added			Volatile Matter Decomposed		
	A. S. Shaken, %	F. S. Not Shaken, %	F. S. Shaken, %	A. S. Shaken, Cc.	F. S. Not Shaken, Cc.	F. S. Shaken, Cc.	A. S. Shaken, %	F. S. Not Shaken, %	F. S. Shaken, %	A. S. Shaken, %	F. S. Not Shaken, %	F. S. Shaken, %	A. S. Shaken, %	F. S. Not Shaken, %	F. S. Shaken, %
1	..	15.3	..	...	595	...	..	24	..	..	..	..	..	..	..
2	..	6.1	..	...	950	...	..	55	..	..	..	..	..	..	..
3	..	8.5	8.5	...	775	845	..	57.5	78.5	..	..	..	..	..	..
4	..	16.2	16.2	...	700	875	..	53.0	68.0	..	71	76			
5	15.5	..	16.4	430	...	690	76.0	..	80.0	60.5	..	66.2			
6	23.2	..	22.3	385	...	770	84	..	89.0	63.4	..	81.0			
7	47.2	..	48.0	405	...	650	92.2	..	88.5	53.0	..	73.3			
				407	754	766				58.9	71.0	74.1			
Average gas per gram raw volatile matter decomposed				690	...	1030									

A. S. = activated sludge.
F. S. = fresh solids.

tile matter content of the ripe sludge was being added, 50 to 55 per cent of the total gas was being produced at the end of the charging period, whereas in the last experiment, with as high as 48 per cent daily additions, 90 per cent of the total gas was produced at the end of the charging period. What is the explanation? Undoubtedly one of the chief factors is the duration of the experiment. If with a constant charge it takes 5 to 6 days for the activities to reach a peak, the shorter the period of digestion the smaller will be the percentage of gas produced at the end of the charging period. From the practical standpoint, however, we must consider uniform operation after the activities are once established. It is also possible that the thermophilic sludge became more and more active as the number of passages during the course of the experiment increased. Previous experiments[2] have shown, however, that once active thermophilic sludge is obtained subsequent passages do not increase its efficiency. On the other hand, even an active thermophilic sludge, when allowed to stand idle (without raw material), will lose its efficiency rapidly, especially if it is stored at high temperatures. This has been found to be the case with non-thermophilic sludge and it is even more important with thermophilic sludge.

Hatfield, Symons and Mills,[1] with daily additions of fresh solids to ripe sludge in the ratio of 1 part fresh organic matter to 90 parts of old organic matter, without sludge withdrawals, found that at 30° to 35° C., 40 to 45 per cent of the gas produced was from sludge added during the previous 24 hours. Daily charges were 1.1 per cent of the original ripe sludge content, on the basis of volatile matter. Since no sludge was withdrawn this percentage became smaller as the experiment progressed. Daily charges were 5 to 10 cc. or 0.1 to 0.2 gram of organic matter per day. In thermophilic digestion at 120° to 125° F. it is possible to obtain practically all the gas in 24 hours, with a daily charge as high as 50 per cent on the basis of volatile matter. This would mean that the sludge added one day can be drawn the next. The tank should accordingly be large enough only to hold the solids accumulation of not more than 2 days. With temperature control at 70° F. the digestion schedule of separate sludge digestion tanks is around 35 to 40 days. The size of the tanks, therefore, can be theoretically reduced to $^1/_{20}$ if a temperature of 120° to 125° F. can be maintained. Whether such temperatures can be economically maintained in winter time or whether the gas produced during the digestion is sufficient to maintain such temperatures remain to be seen. We can, however, confidently say that it is possible to draw ripe sludge 24 hours after the addition of the raw material, provided there is ripe active thermophilic sludge and the temperature is maintained around 120° to 125° F. The sludge will be just as ripe as that drawn at the end of 35 to 40 days at 70° F. It will have an ash content of 45 per cent or

more, a pH value of 7.8 or more, and a B. O. D. per per cent of organic matter of 1500 p. p. m., or less. It is black and inoffensive. To counterbalance the effect of the shorter digestion period in yielding a thin sludge we have the effect of high temperature, which separates the liquid.[2]

There is no indication from our experimental results that a daily charge of 50 per cent is the upper limit. The amount of sludge to be added and the volume of gas to be measured became so high that it was not feasible under laboratory conditions to find out how much more solids could be added. It is proposed, however, to continue the work on a larger scale at the plant.

Considerable sludge rises to the top with digestion at these high temperatures. Shaking is therefore beneficial, although not essential. Shaking was accomplished in the laboratory by hand once a day. With a mechanism that would break the surface scum and bring it into intimate contact with the sludge more favorable results can be expected.

A shorter digestion period was obtained with daily additions than could be obtained with the "batch" process. With the "batch" process the digestion was completed in 12 days, 6 of which were consumed in the initial lag period. Disregarding the initial lag period 6 days is indicated as the shortest time in which complete digestion could be accomplished, with a seeding ratio of 1:2 on the basis of volatile matter. On the other hand, with 50 per cent daily additions, digestion was completed in 24 hours. It has usually been assumed that results of experiments, conducted according to the "batch" process, can be applied to regular operating tanks with daily additions. Under thermophilic conditions it appears, however, that the "batch" process translated into continuous operation leaves a considerable margin of safety. The batch process takes longer and is a more severe strain on the digestion activities.

There are some interesting contrasts between the digestion of fresh solids and the digestion of activated sludge. From our results it appears that the thermophilic digestion of activated sludge can be accomplished just as readily as the digestion of fresh solids. Activated sludge, however, produces less gas per weight of volatile matter. The average yield of gas for the activated sludge was 407 cc. and for fresh solids 766 cc. per gram of raw volatile matter (Table VIII). Volatile matter decomposition was similarly less for activated sludge than for fresh solids, amounting to 58.9 and 74.1 per cent, respectively. Gas produced per gram of volatile matter decomposed was 690 cc. for activated sludge and 1030 cc. for fresh solids. The original assumptions used for the calculations for sludge withdrawal are thus very closely borne out. Per gram of volatile matter added activated sludge produces 47 per cent less gas than fresh solids; per gram of volatile matter decomposed it produces 33 per cent less gas.

Summary

With daily additions of fresh solids or activated sludge and withdrawals of ripe sludge at a temperature of 50° C., under laboratory conditions with 5 gallon carboys, the following conclusions were reached:

1. Nearly 50 per cent of the volatile matter of the ripe thermophilic sludge could be added daily in the form of fresh solids or activated sludge (on the basis of volatile matter).

2. Nearly 90 per cent of such a daily charge was decomposed in 24 hours, as measured by the actual yield of gas.

3. The sludge withdrawn was fully ripe. It had a B. O. D. of 1200 to 1500 p. p. m. per per cent volatile matter; the pH was 7.8 or above, and the ash content was 45 to 50 per cent. It was black and had an inoffensive cooked odor.

4. Activated sludge decomposed as rapidly as fresh solids but yielded less gas. It produced 47 per cent less gas per gram of volatile matter added and 33 per cent less gas per gram of volatile matter decomposed.

5. Shaking the bottle by hand once a day considerably hastened gasification.

6. The yield of gas due to shaking was not materially increased when the shaken and unshaken sludge reached the same degree of digestion.

7. Starting with active thermophilic sludge the maximum rate of gas production was attained in 5 to 6 days and maintained at that level with constant daily charges. But when the charge was omitted one day gas production decreased very sharply the next day.

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Discussion

BY WILLEM RUDOLFS

The bacteria known as thermophilic (heat loving) organisms are a group containing a variety of organisms. They grow best at a temperature range of 120° to 140° F. The bacteria which grow most rapidly at lower temperatures either become inactive or are killed.

In sludge digestion with or without heat control we have been depending upon the organisms which are most active at temperatures between 60° and 80° F. Those active at higher temperatures do not necessarily pro-

duce the same substances during the decomposition processes and do not necessarily grow best at the same reaction. From the results obtained thus far in the laboratory and from semi-plant-scale experiments it seems that the optimum reaction for the group of thermophilic organisms most active in sludge digestion is in the range of pH 7.8–8.2. Once the balanced flora is established this reaction is maintained by the activities of the organisms themselves, similar to the lower reaction of the medium produced by organisms which have their optimum at lower temperatures.

The thermophilic group of organisms appears to destroy the organic matter not only more rapidly than the non-thermophilic group but also more of the resistant material is digested. If under ordinary (82° F.) temperature 50 to 60 per cent of the volatile matter is decomposed in 25 to 30 days, about 70 to 75 per cent is destroyed at 120° F. in 1 to 3 days.

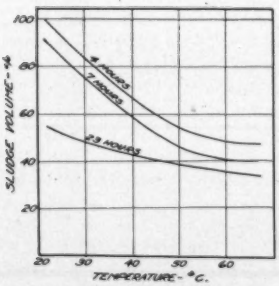

FIG. 1.—Effect of Temperature and Time upon Sludge Concentration.

Judging from the gaseous end-products produced the destruction of the complex organic matter is very similar under thermophilic conditions to that under lower temperature conditions. The composition of the gas is about 70 per cent methane and 20 per cent carbon dioxide. Since destruction of the volatile matter is greater, the volume of gas produced per pound of organic matter is greater under thermophilic conditions. For instance, if at 82° F. the quantity of gas amounts to 6 cubic feet per pound of dry volatile matter, it will be about 7 cubic feet per pound under thermophilic conditions. This larger quantity of gas is produced in considerably less than one-tenth of the time required at 82° F.

Raising large volumes of sludge to a comparatively high temperature and maintenance at 120–125° F. brings up questions of gas collection, heating and insulation of digestion tanks. After the process is well established additions of fresh solids once a day will necessarily result in considerable fluctuations in gas. A short time after the fresh solids are introduced gas production is greatly stimulated, with the result that in 6 to 10 hours a gas peak may be reached, gradually decreasing and dwindling to comparatively small quantities at the end of 24 to 36 hours. When the gas is used for heating purposes this would mean either that a gas equalizing tank is necessary or that the fresh solids must be introduced practically continuously. Continuous introduction of fresh solids can very well be accomplished at larger plants where mechanical sludge removers

are used in the sedimentation basins. It can also be accomplished where the settling tanks have hopper bottoms which allow the continuous discharge of sludge to the digesters. Such practice would seem to be better than the storage of gas until needed, and incidentally it might be cheaper.

The heating of sludge to 120° F. by hot-water coils placed in the tank may lead to incrustations. At lower temperatures these incrustations play a very minor rôle, as has been shown by Downes, supervising engineer of the Plainfield, New Jersey, disposal plant. He found that coils after having been in the tanks for $4^1/_2$ years showed slight incrustation near the hot water inlet to about one-fourth of the length of the coil. He calculates that under the conditions prevailing at Plainfield it will take about 9 years before the entire coil will have been caked about $^1/_4$ to $^1/_2$ inch thick. It is highly probable that caking would be far more rapid and more extensive if hot water coils would be used for thermophilic digestion. It would appear that pre-heating of sludge as practised at Gelsenkirchen, Germany (Prüss) and at North Toronto, Canada, is more logical. Especially, since it would not be detrimental, but probably beneficial, if the sludge was heated to the boiling point.

Heat losses by radiation from tanks kept at 120° F. would be greater than from tanks in which the sludge is kept at 80° F. But due to the greatly reduced digestion time the tanks would be correspondingly smaller and the exposed surface much less. Nevertheless, proper insulation of the tanks would be beneficial when the sludge is pre-heated, to maintain the proper temperature in the digester. The quantity of gas required for the higher temperature is less than for the lower temperature digestion tanks, because the volume of gas produced in one day is at least equal to the volume produced in 25 to 30 days at lower temperatures and the increase in temperature and subsequent heat required is in no way proportional to this larger volume of gas.

The effect of bringing the fresh solids into closer contact with the seed material is under thermophilic conditions considerably intensified. At lower temperatures the effect of stirring might amount to 10 per cent because the time of digestion (30 days) allows the green solids to sink, be brought into contact with decomposing particles, with the embedded bacteria carried upward by the constant evolution of gas bubbles, and mix the active ripe sludge layer lower in the tank When the time factor, is so greatly reduced the more violent gas evolution does not offset the above factors, with the result that even gentle shaking or mixing produces better results. A stirring apparatus combined with continuous charging of fresh solids would be with the present knowledge almost ideal.

At the higher temperature separation of water from the solids is greater than at lower temperature, with the result that the sludge becomes denser. This effect is demonstrated in Figure 1, which shows the increase in den-

sity of fresh solids subjected to different temperatures and for different times. After 23 hours of quiescent compacting the density of the sludge at 22° C. was 15 per cent less than at 50° C. While separation of water from the sludge particles is enhanced at higher temperatures, there is also a tendency toward segregation of materials. The lighter materials are speedily segregated and tend to float, making a mat, while the heavier particles settle to the bottom. When fresh solids alone are heated, the gas driven out of solution causes the solids to float; greasy substances also have this tendency. Ripe thermophilic sludge sinks to the bottom, but partially decomposed material has a tendency to float. If this layer is not disturbed either by gas evolution or stirring it will gradually increase in thickness. However, with continuous operation this material should be broken up and caused to sink. If the floating material is allowed to remain and additional floating solids are added the layer becomes thicker and closely intertwined, with the result that the digestion processes are retarded. When sludge is drawn daily from such a tank to make room for the incoming fresh solids it does not take long before the tank is depleted of "seed" material. With the tendency of sludge to concentrate, forming larger groups of particles, the general tendency for the material is to float, whereupon only the finely divided well-digested mass remains at the bottom. Gentle stirring practised from the beginning prevents this, but when floating material has been allowed to accumulate at the top it seems to be far more difficult to break it up and cause it to sink to the bottom. This detail of operation would be very important in practice because of the danger of withdrawing too much ripe sludge. It takes from three to four weeks to establish the proper balanced and active thermophilic flora. Withdrawing too much sludge would first result in a greatly decreased gas production, followed by the same situation as starting a new tank. New thermophilic sludge would have to be produced before the activities would be again at their maximum. Withdrawal of too much ripe sludge has happened before at several places. This can occur as well at lower temperatures, causing the tank régime to be upset.

Thus far we have not been able to produce foaming phenomena under thermophilic conditions but an effort is being made, so that if it does occur the changes and possible correction can be studied in detail.

With proper operation it appears that thermophilic digestion would be simpler and leave less chance for troubles. When activities are once established and operation is controlled the factors inducing scum formation become far less important than at low temperature digestion because of the large daily turnover of the sludge. The sludge does not remain in the tank for weeks at a time but is discharged before troubles occur. On the other hand when the thermophilic processes have not been properly established and fresh solids are added at too great a rate

the mass might be difficult to handle. If this happens the only possibility is to let the mass rest until well digested.

Calculations of daily withdrawals of ripe sludge are somewhat complicated because of the fact that in addition to the destruction of volatile matter the question of sludge concentration must also be taken into consideration. In practice it would be far better—also for lower temperature digestion—to withdraw as much supernatant liquid day after day as is required to make room for the incoming material. Eventually the tank fills with ripe sludge so that no supernatant liquor can be drawn. This would be the time to draw ripe sludge, and repeating the same process until all the room allowed is taken up by the ripe sludge. If a stirring or pumping arrangement is used for distribution of the fresh solids it is obvious that a few hours resting would be better in order to draw thicker sludge if so required. It is very doubtful, however, whether thicker sludge is an advantage over thin sludge when it has to be dried either on sand beds or dewatered by filtering devices.

Investigations concerning the Formation of Methane from Carbon Monoxide and Hydrogen by Bacteria. R. LIESKE AND E. HOFMANN. *Brennstoff-Chem.*, 1930, **2**, 208.—An account is given of experiments carried out in closed vessels on the conversion of carbon monoxide to methane by bacteria. Bacteria in sludge from water drains and Emscher tanks were found to bring about this conversion according to the equation

$$CO + 3H_2 = CH_4 + H_2O + 46k/cal.$$

These bacteria are gram-positive, non-spore-forming, nonciliate bacilli and carbon monoxide is their only source of carbon. The conversion is greatly influenced by the presence of organic or inorganic colloidal substances in the cultures. Cultures of the bacteria convert the carbon monoxide and carbon dioxide of water gas into methane. Further experiments are necessary before these results can be applied to continuous currents of gas. Tables of results, a diagram of the apparatus and references to the literature are included.—Abs. No. **136**, *British Summary of Current Literature, Water Pollution Research*, Vol. IV, 1 (January, 1931).

Automatic Sludge Stirring Mechanisms

BY A. M. RAWN*

Concurrent with plant-scale experiments upon multi-stage sludge digestion at the Joint Disposal Plant of the Los Angeles County Sanitation Districts, a series of experiments was conducted upon the practicability of self-priming gas lifts for circulating sludge within the tanks.

Multi-stage digestion is a selective process in that only those particles of solids of relatively high specific gravity, and consequently lower organic content, are moved ahead automatically into succeeding tanks, thus hastening their transit through the tanks, while the lighter materials lag and undergo a longer period of detention. The process in its entirety is to be explained in a forthcoming article.

Experiments on multi-stage digestion were conducted in open-top tanks and it was apparent that complete periodical mixing was necessary to develop all the advantages of the process. In the working experiment such mixing was done by injecting a jet of air at the bottom of the tank, thus rolling the bottom sludge toward the top. By moving a one-inch air jet slowly around the bottom of the tank, a thorough mixing could be readily accomplished in a short time.

In covered tanks with gas collection, mixing could be obtained with either pump circulation or by such mechanical stirring devices as are now in common use. It was thought, however, that a more economical means of mixing might be provided if the sludge gas could be captured below the sludge level and made to do the work of an air lift to raise the bottom sludge to the top.

Several types of under-surface gas collection devices were built and operated. In general, each consisted of a submerged hood, designed to trap gases from the sludge below it, and equipped with a riser pipe extending from the hood to the sludge surface, through which the entrapped gases might flow and set up an upward flow of liquid, as in an air lift. Following is the experience with each of the five types illustrated. Each succeeding type, in numerical order, was developed after experience with the preceding:

No. 1: Diagram No. 1 shows the first type constructed. It consists of a pyramidal hood 11 ft. 6 in. square for gas collection and concentration, with a 4 in. pipe extending from the apex of the hood to the sludge surface. Although not entirely successful in operation, it illustrated that the principle was sound, in that it did induce a small upward flow of sludge through the riser pipe. The pitch of the hood top was not sharp enough to permit the ready concentration of gases directly under the riser pipe, and apparently much of the gas adhered to the lower side of the flat sloping roof in bubbles of such size that gas would often leak under the edges of the hood. This fact was apparent when the

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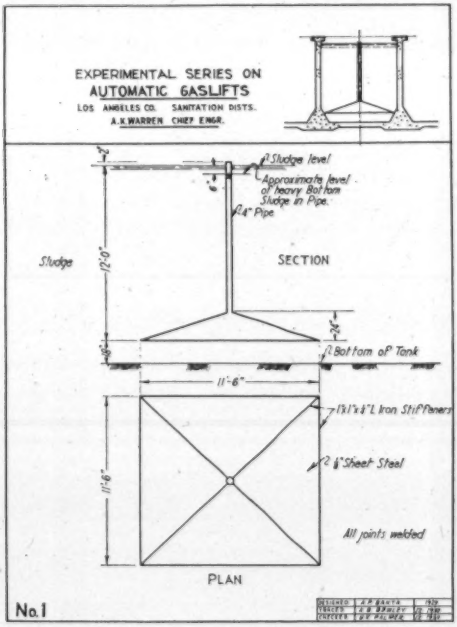
hood was shaken or disturbed slightly, in which case the riser pipe functioned actively for a short interval and then quieted down.

No. 2: No. 2 has the same general characteristics as No. 1 except that the hood is of conical shape with a sharper pitch. It was placed in a 20 ft. deep circular wood-stave tank which was filled with sludge. Heating coils were placed directly under the hood. It worked with reasonable satisfaction but was not active enough to maintain uniform moisture ratios from bottom to top of tank and permitted some stratification. The pitch of the collection cone, however, proved to be about right for apparently no

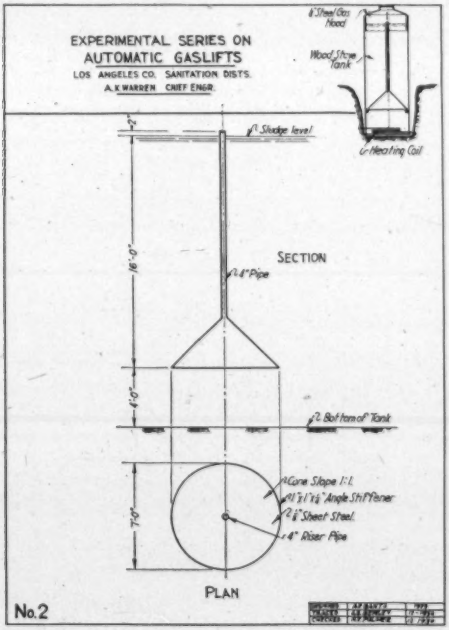


gas adhered as bubbles to the lower side of the hood, as indicated by the uniform flow of gas up the riser pipe.

No. 3: No. 3 was designed with the thought that a strong flow of gas at intervals up the riser pipe would lift more sludge per unit of time, than the slow constant flow had done; also that it would operate to elevate sludge from the tank bottom at intervals regardless of the rate of gas generation. It was built to operate on the air-siphon principle, with the riser pipe extended downward to near the tank bottom, to permit sludge to be elevated from the best seed in the tank.

Gas collects under the hood until the liquor level under the hood is forced down to Elevation "A." At Elevation "A" the gas escapes through the 4-in. priming pipe into the 4-in. riser pipe and continues to escape until the liquor level under the hood has returned to Elevation "B." At Elevation "B" the gas flow is stopped as sludge enters the primer pipe, and no more gas can escape until sufficient has accumulated to again force the liquor level down to "A."

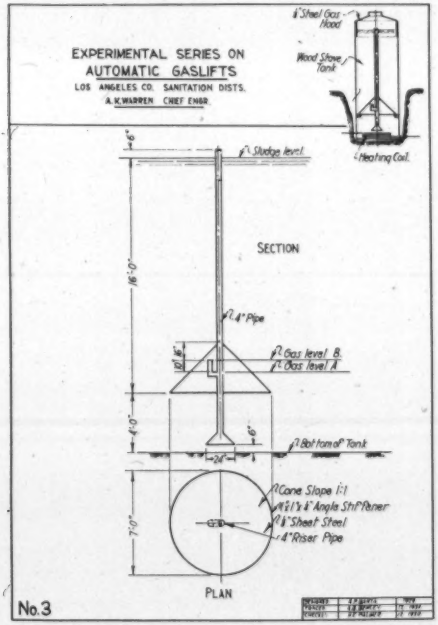
Thus the action is an intermittent one, the interval dependent solely upon the rate of gas production, other factors being equal. No. 3 likewise was installed in the wood-



stave tank under the same conditions as No. 2 and when permitted to blow with the tank top removed, threw sludge from ten to fifteen feet into the air. It operated without serious interruption for a period of a month, discharged at about two-hour intervals and maintained thorough mixing of sludge within the tank, as evidenced by evenly distributed temperatures and uniform moisture content. Stratification was almost entirely eliminated, even when the tank was operated on the fill and draw principle, although a scum of matches, hair and other fibrous material did develop after a number of weeks operation as a fill and draw tank.

No. 4: In an effort to simplify construction as well as to capture more gas and promote a longer period of operation, with the same operation interval, the structure shown in Diagram No. 4 was constructed. It failed to operate automatically. It was found that it would not prime itself alone because gas would trickle continuously through the priming pipe, into the riser pipe at the same rate at which it was captured under the hood, which rate was insufficient to prime the riser pipe and permit the intermittent escape of the gas between levels "B" and "A" as in No. 3 design.

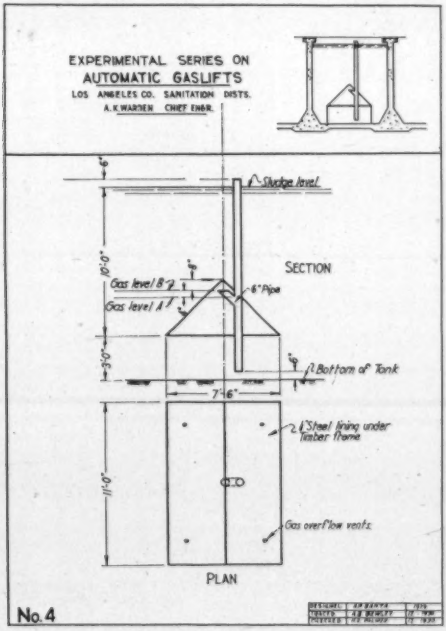
It appeared that, as gas accumulated under the hood, forcing the liquor level down



to "A," the surface area of the liquor exposed to the gas was so great when "A" level was reached that the vertical displacement became relatively small per unit of gas collected, which permitted the slow leakage through the priming pipe. Experience with this design indicated that it would be necessary to provide a gas collection hood of smaller section, which would fill more rapidly and provide the proper impetus for priming.

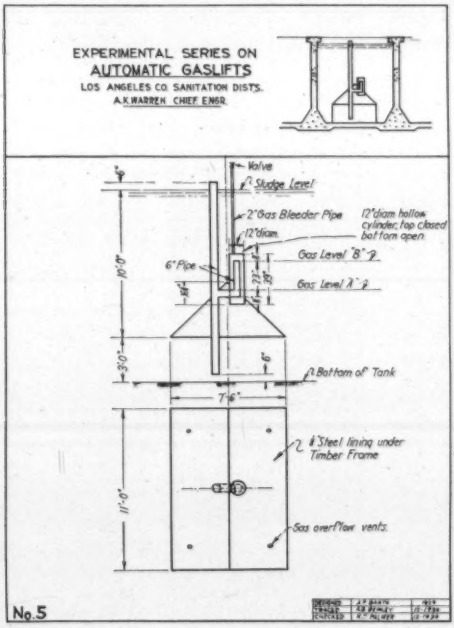
No. 5: The structure shown in Diagram No. 5 resulted from this conjecture. It operated perfectly for a period of three weeks in an open tank, shooting regularly at

intervals of eleven to twelve minutes. As the gas accumulates under the hood in No. 5 and forces the liquor level downward, the sludge seal at the lower side of the 12-in. cylinder, which is open at the bottom and closed at the top, is eventually broken, and gas enters the cylinder in large bubbles. Each large bubble of gas entering the cylinder from the hood causes a considerable vertical displacement of liquor in the cylinder because of the latter's relatively small cross-section, with the result that the bubble of gas, which upon entering the cylinder fills it down to level "A" or a little below, has the effect of also forcing a sufficient charge of gas through the priming pipe to prime the riser and permit the escape of the cylinder gas back to level "B."



Stirring in this manner has the advantage of throwing out from the top of the riser pipe a quantity of the most completely digested sludge in the tank, which can be deflected laterally over the top of scum or foam. In the experimental work, the stirring devices Nos. 3 and 5 prevented stratification, equalized temperatures in the heated tank and in general did the work which other sludge mixing mechanisms and operations might

accomplish. If stratification and decantation of supernatant liquor is at any time desirable, the valve in the 2-in. bleeder pipe may be opened, effectively preventing any gas accumulation under the hood. In controlled digestion, circulation and re-seeding within the tank become important, and it is thought that the apparatus described will be a beneficial means to such an end. It can be used in any type of tank without reference to shape or size.



Comparative costs between any of the types of mixers herein described and gas pumping to promote the same result indicate economy in use of the latter where large installations are to be made. Where small separate-digestion tanks are to be built, pumping equipment assumes a higher relative cost, with the additional expense of operation and maintenance. It is thought that in small tanks the automatic gas lifters described as No. 3 or 5 could be used as stirring devices to good advantage.

Activated Sludge Digestion at Salem, Ohio*

BY ANTHONY J. FISCHER**

Description of Plant

The Salem, Ohio, plant consists of a mechanically cleaned bar screen 2′ wide with $1\frac{1}{4}$″ clear openings; an aerated grit channel 3′ wide × 3′6″ deep × 22′6″ long; two primary clarifiers 35′ × 35′ × 8′ side water depth; three spiral-flow aeration tanks each divided into two compartments 9′ wide × 8′6″ water depth × 100′ long; two secondary clarifiers identical with the primary units; a 50′ dia. × 20′ digester; a 35′ dia. × 10′ sludge storage tank; two 4″ diaphragm sludge pumps; two 3″ centrifugal sludge circulating pumps; three positive displacement blowers; and a 4″ centrifugal pump for general utility.

In addition, there is a large sand filter bed area and a chlorination basin from an old plant. The filter beds are used for sludge drying and for handling storm flows in excess of 1.5 m. g. d. The chlorination basin averages 19′ in width and is 109′ long. Its water depth varies from 3 to 5 feet. At present this tank is being used for tertiary sedimentation. There are provisions for chlorinating the flow before or after this unit.

The plant was designed for an ultimate flow of 1.5 m. g. d. from a contributing population of 15,000. The present average dry-weather flow is 1.0 m. g. d. and the contributing population is estimated to be about 7000. The sewage is domestic except for a small amount of creamery waste and is from a separate system. During wet weather, however, the high rate of infiltration increases the flow to as high as 6 m. g. d. Normally, the suspended solids content of the raw sewage is about 200 p. p. m. The removal in the primary clarifiers averages from 45 to 50 per cent, and the overall plant removal about 90 per cent.

Digester

The digester is of the gas-collection type and is equipped with a Dorr mechanism and sludge-heating coils. The roof and floor of the tank are substantially flat, sloping only $\frac{1}{4}$″ per foot.

Raw sludge can be introduced at two points through the roof through 4″ pipes. A 6″ pipe connects the sludge pumps to the center discharge cone so that digested sludge may be withdrawn or recirculated in the digester. A 6″ scum drain permits the withdrawal to the storage tank of any scum that may accumulate in the gas dome.

The clear supernatant liquor displaced by raw and waste activated

* *Presented at the 8th Annual Meeting of the North Carolina Sewage Works Association, Hendersonville, Oct. 15, 1930.*

** *Sanitary Development Engineer, The Dorr Company, New York.*

sludge is returned to the primary clarifiers through two 8″ overflow pipes that enter the digester 18″ below the under side of the roof.

Gas Collection and Sludge Heating System

The gas-collection system is of the usual type, consisting of gas dome, moisture trap, meter and pressure relief trap. The gas is utilized for heating the digester and for burning the coarse screenings in a Buffalo Co-operative Stone Co. incinerator of 6-bushel capacity.

The digester sludge heating system consists of two coils of $1^1/_2$″ wrought iron pipe connected to headers, a centrifugal circulating pump, a water meter, and a 6-burner Bryant boiler with automatic temperature regulator. The headers in the digester are connected to the rest of the heating system by 2″ pipes insulated by 6-ply asbestos and placed in a 15″ tile encased in concrete. Thermometers placed in the line measure the ingoing and outgoing water temperature.

FIG. 1.—Sewage Treatment Works, Salem, Ohio.

Proposed Operation

As originally planned, raw and waste activated sludge were to be pumped directly to the digester while digested sludge was pumped to the unheated storage tank. After a sufficient quantity of digested sludge had accumulated in the storage tank, it was to be drawn to the sludge drying beds. Such an arrangement permitted the winter storage of sludge and at the same time reduced the volume of the heated digester. This reduces the heat losses, cuts down the volume of digester supernatant liquor returned to the primary settling tanks, and gives more flexible digester operation.

Flexibility

Provisions were also made so that waste activated sludge could be pumped to the primary clarifiers, to the sludge storage tank or to the sludge drying beds. Later, a 2″ pipe was connected to the discharge end of the

return sludge pumps so that waste sludge could be returned to the primary clarifier influent channel without additional pumping.

Raw or digested sludge could also be pumped to the storage tank or to the sand beds, while the digester overflow could be returned to the primary clarifiers or to the storage tank.

Actual Operation

The primary system was put in operation November 5, 1928. At that time the digester was still under construction so the settled sludge was pumped daily to the unheated storage tank where it remained in a dormant state until the following February, when the entire contents of the storage tank were transferred to the digester. At that time the aeration units were also started up.

This large volume of raw sludge was then heated by means of a coal-fired boiler connected to the digester heating lines. No lime was added

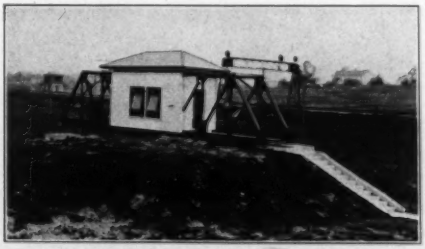


FIG. 2.—Dorr Digester at Salem, Ohio.

and acid fermentation started, accompanied by the formation of a heavy scum and a slight amount of foaming. This foaming subsided after the temperature was raised and a sufficient amount of ripe sludge had formed. The same layer was gradually reduced and was entirely absent after about May 1, 1929. At that time the sludge temperature had been raised to 65° F. and about 3500 cu. ft. of gas were being obtained each day.

A few weeks after the aeration tanks were started up, waste activated sludge was being pumped to the digester either by means of a 150 g. p. m. centrifugal pump or by means of a diaphragm pump set to deliver about 40 g. p. m. When the digester was full it was noted that the supernatant liquor contained a large amount of suspended solids and that the sludge line was very indistinct.

Although the overflow liquor settled out very well in the primary clarifier, this action was undesirable as the pumping costs were increased,

and the highly putrescible, non-settleable solids were detrimental in the aeration tanks.

The following methods of solving these difficulties presented themselves:

1. Pre-settling the waste activated sludge in the primary clarifiers.
2. Diverting the digester overflow to the storage tank and then to the sludge beds.
3. Using the storage tank for re-settling of the overflow, pumping the settled solids back to the digester and allowing the supernatant to flow back to the primary clarifiers.
4. Pumping the activated sludge continuously to the digester at a very low rate.

Introducing the sludge at a slower rate did not help materially as the large volume of overflow still had to be taken care of. It did, however, prevent bulking of sludge in the aeration tanks due to the sudden discharge of large volumes of overflow liquor to the aerators.

As a very large sand bed area was available, it was next decided to divert the overflow to the storage tank, from which it was pumped to the sludge beds. This was done until November 22, 1929. Then attempts to pre-settle the activated sludge and to return the digester overflow to the primary clarifiers were made. Accordingly, the waste sludge was pumped to the clarifier influent channel at a 30 to 40 g. p. m. rate. This rate was found to be too high and some of the flocs were observed flowing over the effluent weirs.

Sludge was now entering the primary clarifiers from three sources as follows:

1. Raw sludge, normally amounting to about 1000 gallons per day.
2. Waste activated sludge amounting to about 8000 gallons per day.
3. Sludge from the digester overflow, amounting to about 10 per cent of the volume of sludge being pumped to the digester.

Obviously, unless these combined sludges concentrate in the clarifier a recirculation system is set up. Such a condition would be detrimental as it would increase the heat losses in the digester and foul the primary effluent.

It was actually found that 18 hours of continuous pumping were required to keep the clarifiers clear of sludge and that this gave us a condition similar to that when we pumped the activated sludge directly to the digester.

These experiences indicated that it was necessary to waste the activated sludge continuously at a low rate to the primary clarifiers, secure maximum concentration of the combined raw and activated sludge in the clarifiers, and pump the concentrated sludge to the digester for short periods at frequent intervals. If possible, the sludge should be pumped continuously at a low rate.

In February, 1930, the waste-sludge line connected to the return-sludge pump discharge was installed. With this arrangement it was possible to waste sludge at a rate as low as 5 g. p. m. It was found that this could be stepped up to as high as 15 g. p. m. without having the floc go over the effluent weirs.

A 2-foot sludge blanket was next built up in the tank before sludge was pumped to the digester. Pumping three times a day to the digester ten minutes each time was then found to be sufficient. Analysis of the raw-activated sludge mixture made each time the sludge was pumped showed a maximum of 21.8 per cent solids, a minimum of 7.0 per cent and an average of 9.45 per cent solids over a period of two months (Feb. and March, 1930). The samples analyzed were taken at the end of pumping.

The effect of this method of operation was to secure a relatively clear digester overflow, a distinct sludge line in the digester, greater gas production and a denser digested sludge.

The beneficial action of the mechanism was evidenced in that the gas was evolved rapidly at a uniform rate, while scum was entirely eliminated. During the intervals between sludge pumpings the gas evolution caused the liquid in the digester to drop about 12″ to 24″ in the manhole at the side of the tank. It was noted, however, that when the mechanism was stopped for about one-half hour while samples were being taken, the gas evolution would fall off and the liquid level would rise and overflow due to the entrainment of gas in the sludge.

Operating Results

Up until May 8, 1930, no sludge had been drawn to the drying beds. The overflow liquor, however, was sent to the sludge beds from October, 1929, to the following February, except for a period of two weeks. The total solid content of the overflow during this period was about 2.0 per cent. After the operation was straightened out, this solid content dropped to 0.25 per cent.

The following table shows weekly averages of the overflow liquor from February 12 to April 8, 1930:

Date	Total Solids, %	Total Ash, %	Suspended Solids, P. p. m.	Settleable Solids, % by Vol.	Suspended Solids after 2 Hrs. Settling, P. p. m.
Feb. 12–18	0.249	46.6	1164	3.37	183
19–25	0.251	44.7	1014	2.61	141
26–Mar. 4	0.235	44.7	718	2.09	97
Mar. 5–11	0.238	44.0	946	2.38	102
12–18	0.242	39.2	951	2.23	153
19–25	0.266	42.5	1183	2.93	152
26–Apr. 1	0.271	39.1	1100	2.68	161
Apr. 2–8	0.314	44.4	2020	3.80	156

Settleable solids were obtained by allowing the overflow liquor to settle in an Imhoff cone for two hours.

These figures show that the total solids in the overflow were low, averaging 0.258 per cent. Of these solids, 1137 p. p. m. or 44 per cent were suspended. Of these suspended solids, 994 p. p. m. or 90.2 per cent were settleable and should to a large extent be removed in the primary clarifiers.

A typical example of solids, ash and pH values at various depths in the digester is given below:

SAMPLES COLLECTED APRIL 1, 1930

Depth below Tank Surface at Side	Solids, %	Ash, %	pH, Value	Remarks
0′ (top)	0.217	43.5	7.1	No scum present
5′	0.218	46.8	7.1	Temp. 78°
5¼′	0.340	43.5	7.1	
5½′	0.823	48.2	7.1	Sludge line
6′	6.30	55.0	7.1	
7′	6.88	56.5	7.1	Temp. 82°
10′	8.30	58.3	7.1	
13′	8.08	57.2	7.1	
18′	8.28	58.8	7.0	Temp. 83°
20′	10.47	58.1	7.0	

Usually, by means of a bottle fastened to a sample pole the sludge level could be determined to within 2 to 3 inches.

One of the effects of pre-settling the activated sludge and pumping a thick combined sludge to the register was to concentrate the digested sludge and so increase the capacity of the digester. For example, the following sludge solid contents were noted at various depths at different sampling periods:

DEPTH BELOW SURFACE AT SIDE OF DIGESTER

Date, 1930	5′	7′	13′	20′
Feb. 21	0.198	6.35	6.12	7.42
Mar. 3	0.204	6.65	6.63	7.39
Mar. 13	0.211	6.87	7.28	9.60
Apr. 1	0.218	6.88	8.08	10.47

The sludge depths on these dates were: Feb. 21st, 14′0″; Mar. 3rd, 14′6″; Mar. 13th, 14′0″; Apr. 1st. 14′2″.

The digested sludge was black in color, was non-odorous and dried readily on the sludge beds.

Tests showed that on an average 1305 lb. of dry solids were added daily to the digester. Of these, 845 lb. or 64.7 per cent was volatile matter and 460 lb. or 35.3 per cent was ash.

On Feb. 21st there were 122,500 lb. of dry solids in the tank, and on

April 1st 147,000 lb., an increase of 24,500 pounds. Now, the total addition during this period was 51,000 lb. so that the solids reduction amounted to 26,500 pounds.

This reduction was due to actual digestion and to loss of solids in the overflow. Of the overflow solids lost, totaling 660 lb., 560 lb. were dissolved and 100 lb. suspended.

The solids and volatile matter reductions may be calculated as follows:

	Total Solids	Volatile Matter	Ash
Added (Feb. 21–Apr. 1)	51,000 lb.	33,000 lb.	18,000
Remaining (Feb. 21–Apr. 1) (including overflow solids)	25,160	7,160	18,000
Digested (Feb. 21–Apr. 1)	25,840	25,840	...
% Digestion	50.6	78.0	...

The total gas production over this period was 271,409 cu. ft., averaging 6950 cu. ft. per day. This gives 8.22 cu. ft. of gas per pound of volatile matter added or 10.5 cu. ft. per pound of volatile matter digested.

Average temperatures, amount of heating water circulated, and cubic feet of gas per day, during February and March, 1930, were:

Raw sewage	47.9° F.
Air (max.)	43.7°
Air (min.)	26.2°
Digester (top)	78.0°
Digester (bottom)	81.8°
Heating water (in)	124.9°
Heating water (out)	117.4°
Heating water circulation—c. f. d.	4030
Gas c. f. d.	7880

Summary

Experiences at Salem, Ohio, showed that activated sludge can be satisfactorily digested in separate sludge-digestion tanks.

The greatest difficulty encountered was in securing a relatively clear digester overflow. This was accomplished by wasting activated sludge at a low rate to the primary clarifiers, concentrating the combined raw-activated sludge mixture, and pumping to the digester for short periods at frequent intervals.

The above method of operation gave an overflow containing only 0.25 per cent total solids, cut down the digester heat losses and produced a thicker digested sludge.

Digestion reduced the total solids 50.6 per cent, and the added volatile matter 78.0 per cent.

The gas production averaged 8.22 cu. ft. per pound of volatile matter added or 10.5 cu. ft. per pound of volatile matter destroyed.

The raw sludge pumped daily averaged 9.45 per cent solids, 35.3 per cent ash; while the digested sludge contained 10.47 per cent solids, 58.1 per cent ash.

Acknowledgment

The Salem plant was designed by Mr. F. S. Barckhoff, city engineer, Mr. C. C. Hommon of Canton, Ohio, was consulting chemist in design.

The writer wishes to acknowledge the assistance of these engineers and the coöperation of the city officials of Salem; and of Mr. F. Preu and Mr. W. M. Bingley of the Dorr Company who assisted in the analytical work.

Water Movements and Infection in Two-Storied Fresh-Water Clarification Plants (Die Wasserbewegung und Infizierung in zweistöckigen Frischwasserkläranlagen). W. REINHART. Supplement to *Gesund.-Ing.*, Series 2, No. 10. Verlag R. Oldenbourg, Munich, 1930. 13.50 M.; *Gesund.-Ing.*, 1930, **53**, 465.—The problem of the "infection" of the sewage in the upper part of a fresh-water clarification tank by movement between settling chamber and septic chamber through the slits was examined in an experimental plant. The factors examined as being of most influence were the amount and speed of the water, the concentration of the contents of the septic chamber, insertions in the settling chamber and in the inlet and outlet and the temperature. The results are given in tables, diagrams and charts.—Abs. No. **92**, *British Summary of Current Literature, Water Pollution Research.* Vol. IV, 1, (January, 1931).

Chlorination of Sewage and Sewage Effluents*

BY GEORGE B. GASCOIGNE**

Early history records the recommendation by the Royal Sewage Commission of Great Britain that the London sewage be chlorinated with bleaching powder for the purpose of deodorization. Dibden put this recommendation into effect in 1884. In 1892 disinfection of sewage occurred for the first time at Hamburg, Germany, while at Brewster, N. Y., at about the same time, or a little thereafter, the same procedure was followed. Dr. Samuel Rideal made important studies in sewage chlorination about 1905 which indicated that the production of chloramines and similar products in the sewage was a valuable aid in disinfection.

In this country our activities in disinfection orient about the work of Prof. Phelps at Boston, Mass., and Redbank, N. J., in 1906. Then it was that sewage chlorination was established as a practical and economical disinfection process. From this time forward the chlorination of sewage has come into increasing use and through the efforts of the Chlorine Institute, with the coöperation of independent investigators, the fundamentals of this subject have become better understood. Recent investigations and plant operations have demonstrated also the inadequacy of early data and the need of further research. Also, newer uses for chlorine in connection with sewage treatment have been developed and put into practice.

Theory and Application

A number of books are available which give the theory underlying the application of chlorine to sewage for various purposes. Also, these books discuss the apparatus available, the dosages required and the efficiencies obtained. Therefore, no space or time will be used in this paper for discussing these particular features of the problem.

Developments in Chlorination

In earlier practice bleaching powder, and later liquid chlorine, was applied, usually to the effluent from a settling tank to disinfect sewage. Long periods of contact were then thought necessary and fixed dosages of chlorine were used without regard for the variations in quantities and quality of the sewage reaching the point of treatment. In the application of the process the importance of these features was appreciated. It remained for W. D. Tiedeman of the New York State Department of Health with the coöperation of L. H. Enslow of the Chlorine Institute to establish that when a high degree of disinfection was desired, it was necessary to maintain

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a slight excess of available or residual chlorine in the treated sewage. Likewise, these men demonstrated that the chlorine requirements of sewage varies with seasonal changes, and that economy results from frequent use of the residual chlorine test with varying chlorine dosage.

To my knowledge the first attempt to determine the effect of suspended solids upon the efficiency of disinfection occurred in Cleveland in 1918 under the direction of Harrison P. Eddy. Experiments were conducted from which the following conclusions were drawn:

(*a*) Present-day sampling procedure for raw sewage does not give a true index of actual conditions in that many bacteria, say 40 per cent, elude detection.

(*b*) Disinfection is of relatively little value unless subject to very careful control according to the quantity and quality of the sewage.

(*c*) Disinfection will be more efficient if the suspended matter is removed before the chlorine is applied. The degree of efficiency indicated by the usual method of analysis is then approached.

(*d*) The removal of the coarser suspended matter does not aid disinfection to the same extent as the removal of the same quantity of fine matter because the latter contains the greater number of organisms.

The preceding viewpoints had considerable weight in determining the type of the present Westerly and Easterly sewage plants of Cleveland. At the former the sewage is settled in Imhoff tanks and the settled sewage is chlorinated, while at the latter the sewage after passing bar gratings, is chlorinated, both operations occurring in the summer time or during the bathing season. In this manner satisfactory conditions for supposedly efficient disinfection would occur at the Westerly Plant while at the Easterly Plant efficient disinfection of a sewage with practically no treatment beforehand, simply the passing of the sewage through bar gratings with $^3/_4$-inch openings, could be demonstrated.

The degree of penetration of suspended solids by chlorine has been further studied by Tiedeman for ineffectively settled sewage, by Scott and Pool for fine-screened sewage, and by Sandquist and Foote for crude sewage, first passed through a macerating impeller. In each case a residual chlorine content from 0.3 to 0.5 p. p. m., after a contact period of 10 minutes, apparently proved sufficient to insure satisfactory disinfection. Without residual chlorine the suspended particles were ineffectively penetrated, if at all.

Prechlorination vs. Postchlorination.—In connection with chlorination sewage in settling tanks which are properly operated, it has been indicated that chlorination of the influent instead of the effluent is, for several reasons, preferable in practice. Not the least of the reasons is the more uniform and dependable action. Under this plan it appears that less chlorine is required for many plants and that the chlorine oftentimes can be applied up the trunk sewer ahead of the plant. Judging from the performance of plants practicing prechlorination, and from experimental stud-

ies, it appears that solids from even a heavily chlorinated sewage, when mixed with digested sludge, will be as readily digested as are the raw solids when so mixed without chlorination. Furthermore, it appears that the initial decrease of the pH value of the sludge mixtures in digestion tanks is prevented to some extent by prechlorination. The flow chambers of the settling tanks are kept in a fresher condition—solids do not tend to belch to the surface—therefore, odor improvement is marked.

The Newer Uses of Chlorine

Under this heading may be mentioned a certain practice of today which had its foundation laid many years ago. In fact, this is true of many of the fundamental principles of sewage treatment which remain today the same as they were when originally discovered.

Controlling Odors at Sewage Works.—The control of odors near a sewage works is perhaps the outstanding development in sewage chlorination. Chlorine in moderate dosages, when applied to the sewage at points along the contributing sewer, upon its arrival at the treatment works, after preliminary treatment or prior to its application to trickling filters and to the gases which come from the decomposition of organic matter, deodorizes and prevents further production of hydrogen sulphide, either in the sewer or the sedimentation tanks, and its liberation by aerating devices. In this country there are more than fifty plants now employing chlorine for odor correction purposes, among which may be mentioned Plainfield, N. J., Flint, Mich., San Bernardino, Cal., Schenectady, N. Y., Alliance, Ohio, Independence, Kansas, and others.

Stale and septic sewage can be deodorized by the application of chlorine, but usually a more economical procedure is to add smaller quantities of chlorine to the fresh sewage to retard bacterial increase and the attendant decomposition of the sewage, with production of hydrogen sulphide gas.

In the summer of 1921 apparatus was installed by the writer at the West 58th Street sewer outlet of Cleveland, to determine whether the odors arising from the sewage could be destroyed by chlorine gas. With the application of the chlorine the distinctive sewer odor disappeared and, while the test appeared satisfactory, the amount of chlorine required and the manipulation of its control then appeared somewhat difficult to determine. This experiment led to the installation of a large chimney at the Westerly Sewage Works, so constructed that the gases or odors about the plant could be collected, if need be, by forced ventilation, and then chlorinated. As yet this has not been done, although the layout is such that it can be used if the need arises.

At the Milwaukee Sewage Works the city deodorizes stack gases from the sludge drying plant by the application of chlorine. This procedure

has been used for a number of years and it has proved effective and the least expensive of a number of schemes.

At Los Angeles, Cal., a deodorization scheme, both novel and interesting, has recently been adopted. At one of the sewage lift stations in the city proper, a fine spray of chlorine water in the pump sump is reported to have proved helpful. A more effective application of the chlorine was obtained in the form of hypochlorous acid, liberated through nozzle sprays. In the process chlorine water from an ordinary chlorinator is discharged upward through a tower filled with finely crushed limestone. The chlorine is converted thereby into hypochlorous acid. The process has proved quite effective, with a low chlorine consumption. The station is located within about 50 feet of an open air vegetable market. Enslow, who is responsible for this installation, states that it is a new application of an established method of producing hypochlorous acid for bleaching purposes.

Relieving Pooling of Filters.—The surface clogging of trickling filters interferes with their capacity and ability to produce a satisfactory effluent. This clogging causes pooling, which is frequently attributed to algae and fungus growths.

The temporary application of chlorine to sewage in the dosing chambers at the Schenectady Plant for filter fly control relieved the filtering stone of surface clogging which caused pooling. Later the same effect was noted at New Braunfels, Texas, with a filtering media of 1 inch or smaller in size, and later still at Canton, Ohio, where slag is used in the filters. At Lackawanna, N. Y., a pronounced pooling condition was corrected by a short period of chlorination with a nominal expenditure for chlorine. Recently at Elgin, Ill., a more severe pooling condition has been corrected by chlorination. Bleaching powder applied to the siphon chambers also has been effective at Bloomington, Ill., and at Rochester, N. Y.

The efficiency of trickling filters seems to be increased following the application of chlorine or bleaching powder. Also, the more economical procedure is to chlorinate the night flow of sewage only, repeating nightly until the filters are clean. The applied sewage should contain from 3 to 5 parts per million or thereabouts, of residual chlorine, and the necessary dosage is usually at the rate of about 25 p. p. m. calculated on the diminished night flow. It is significant also that the night flow has about one-half the chlorine demand of the day flow. Apparently not more than one thorough treatment of the filters per season is required to prevent recurrence of pooling.

The prevention of filamentous growths by chlorination may have some bearing upon the desirability of using large sizes of stone for filter beds. If a return to smaller size with increased efficiencies may prove feasible, thus leading to heavier loadings, experience at Schenectady and elsewhere indicates that chlorinated filters might stand increased rates of sewage

application. Dr. Rudolfs at the New Jersey experimental station points out that filtering media with thin films are far more efficient than those with heavy films. Dr. Mohlman points out in editorial comment in SEWAGE WORKS JOURNAL of July, 1930, that chlorination for cleaning filter stone is effective, simple and economical. At Schenectady, N. Y., nitrification seemed to increase to the maximum recorded for the plant following drastic chlorination, and at Canton, Ohio, the filter efficiencies improve following moderate prechlorination of the crude sewage.

The chlorination of sewage applied to filters seems to reduce breeding of flies in the filters, but chlorination *per se* does not seem to serve as sufficient control of the fly nuisance. With our present knowledge, flooding of the beds must be depended upon for this purpose. There may be something also in the idea that certain insects, such as spiders, prevent the propagation of flies.

Reducing Oxygen Demand.—When crude or settled sewage is chlorinated apparently a substantial amount, estimated in instances to exceed 90 per cent or more of the chlorine applied, enters into combination with substances in the sewage. This absorption of chlorine must be satisfied before efficient disinfection can be obtained. Apparently the same substances which exhibit chlorine demand are rapidly oxidized and remove the dissolved oxygen from the receiving waters.

Judged from published data by several independent investigators, sewage which has been chlorinated exhibits a reduced demand for oxygen. Also, actual plant operations indicate this conclusion. The extent to which chlorine reduces the oxygen demand is dependent upon the character of the sewage, and in some instances there has been reported a reduction of 25 per cent, if not more. Also, with the stronger sewages, the reduction would be greater. Likewise, the effect of chlorination during the first 24 to 48 hours is very marked, as would be expected from the sterilization effect and retarded bacterial reproduction. There appears to be also a true or permanent reduction of the oxygen demand value which persists for a substantial period, say 20 days, of incubation of seeded samples of sewage.

At the Easterly and Westerly Sewage Works of Cleveland, where the largest chlorination plants of this country are in operation during the summer or bathing season, considerable work has been done to show what reductions in oxygen demand actually occur. Obtaining data upon this subject, and for this particular purpose, is rather difficult, as there is little opportunity to demonstrate whether or not the effect of chlorination is simply one of inhibition or permanent, since the treated sewage is dispersed into the waters of Lake Erie. I am under the impression that the chlorination experiments during the past summer at Indianapolis upon a settled sewage seem to indicate that the action was largely one of inhibition.

This statement is based upon observation of the river into which the sewage is discharged, and any more precise conclusion must await the publication of data which are not available at this time.

Enslow advances the theory, based upon observations of investigators in other fields of chlorination and observations in the sewage and industrial waste field, that chlorine does not actually oxidize the putrescible matter in sewage, but rather combines with unsaturated organic compounds to produce non-putrescible compounds, many of which are actually mild disinfectants in themselves. Dr. Rideal in 1904 observed the production of bodies in chlorinated sewage which were similar in effect to chloramines. It is known that nitrogenous organic compounds upon decomposition exhibit a marked affinity for chlorine, and urea, the main constituent of urine, is decomposed by chlorine. Hale has published his observations of the effect of chlorine in organic nitrogenous matter in sewage.

If we can expect a reduction of oxygen demand of 35 per cent by efficient sedimentation, the reduction assisted by chlorination may apparently be increased to say 50 per cent. That such a reduction may prove sufficient during limited periods, when sedimentation alone is insufficient, has been suggested by Baity, Rudolfs and Mohlman. Further, the chlorination of treated sewage or by-passed settled sewage may prove advantageous as a temporary measure for sewage works unable to cope with peak conditions. Probably the process is also applicable when sufficient dilution is not available at the point of discharge from a plant but is available a short distance away. In such instances chlorination may serve to control odor nuisances or unsightly conditions.

Protection to Sewers.—The protection of masonry sewers against disintegration appears to be a hot weather problem, just as is odor prevention. The hydrogen sulphide converted to sulphuric acid attacks the concrete work and mortar joints in masonry sewers. An example of the value of chlorination for preventing masonry attack is found in Orange County, Cal., where contributing cities and towns partially chlorinate their sewage prior to discharge into the long trunk outfall sewer. The process has been in use for over a year, merits consideration and is reported to be effective. A detailed account of the problem appears in the September, 1930, issue of *Water Works and Sewerage.*

Chlorination and the Activated Sludge Process

In Canada a solution of bleaching powder is frequently applied to the returned sludge of activated sludge plants in order to correct disturbances in the process which result in an inferior effluent. This treatment was first employed by A. V. DeLaporte of the Ontario Provincial Health Department experimentally, and since by several plants.

In England, at the Barnsley Plant of the activated sludge type, H. D.

Bell has reported considerable improvement in plant performance from application of bleaching powder to the crude sewage prior to sedimentation. Apparently greater benefits result from a secondary application made to the returned sludge at the point of admixture with the settled sewage. It is reported that during 1929 the plant could take care of the entire sewage flow for the first time without by-passing during the summer. In addition, the quality of the effluent was improved.

Chlorine is reported to have been used to clean filtros plates by applying the dry gas to the air manifolds. If such a procedure can be fully demonstrated it would constitute an inexpensive means of plate cleaning. The suggestion has been made also that a minor quantity, say about 1 p. p. m., of chlorine applied to the sewage in the air supply would prove of value for the activated-sludge process during summer conditions. It is hoped that arrangements can be made somewhere to give this idea an early trial.

The largest use of chlorine in conjunction with the activated sludge process is for production of ferric chloride or chlorinated copperas, for use in sludge dewatering. Milwaukee, Charlotte and Gastonia, N. C., Indianapolis and Pasadena employ at times ferric chloride. Houston, Texas, used chlorinated copperas apparently because of its greater economy.

Incidental Effects from Sewage and Industrial Waste Chlorination

Chemical precipitation has been employed in treating wastes from industrial plants sometimes satisfactorily and sometimes otherwise. Chlorination of the effluent from precipitation tanks and of trickling filter effluents from creamery waste plants has proved beneficial in eliminating fungus growths from stream beds and preventing odor nuisances along the stream. Chlorine is used for this purpose in cannery plants in Wisconsin and New York.

Ordinarily creamery wastes create a considerable burden for municipal sewage treatment plants. In California and Arizona the use of creamery wastes for irrigation is practised, I understand, without odor nuisance and, further, the procedure constitutes an economical means of disposal. Moderate chlorination of the fresh wastes as they leave the creameries indicates that decomposition on the land is prevented during the period of absorption. The process is in use at Phoenix, Arizona, and Wasco and Tulare, California.

The use of a series of trickling filters in two-stage treatment is proving quite acceptable at a plant in Mason City, Iowa, as compared with the activated sludge process previously employed for disposing of the packing-plant wastes. Chlorine is applied to prevent septic action and odors. The use of trickling filters in series seems to be a dependable procedure worthy of serious consideration for this particular purpose.

The discharge to a stream of paper mill "white water" containing valu-

able ingredients is wasteful and creates a stream pollution problem. Recently an attempt has been made to recover this "white water" for return to the mill. Chlorination of the "white water" is practised to prevent slime growths and possibly putrescence.

There are a number of incidental effects from sewage chlorination which are worthy of mention. Additional data or research work is necessary to establish specific usage. Among these it may be mentioned that when an excessive amount of grease is present in sewage or industrial wastes in an emulsified state, chlorine may be applied to break this emulsion, thereby allowing liberated grease to float and be collected. Evidence is still lacking to prove definitely whether or not the application of chlorine to sewage promotes or retards sludge digestion. There are some instances where foaming of settling tanks is reported to have been corrected by its use, and that chlorine applied to the influent of secondary-settling tanks improves their operation and reduces the de-nitrification and depletion of oxygen which takes place in such tanks in warm weather.

Cost of Chlorination

The cost of chlorination for various purposes has a wide range and depends in no small way upon a number of conditions which are usually quite local in character. Consequently, cost information must be used cautiously. For convenience, the cost of this process may be divided into the headings of chlorine, equipment and labor.

Chlorine.—Chlorine is now available for purchase in 100 and 150-lb. cylinders, ton containers and tank cars, the price depending upon the type of container and upon the distance of shipment or freight cost. With cylinders purchased as needed, the price will range from 6 to 7 ¢ per lb. of chlorine, with cylinders in car-load lots, from 4 to 5 ¢ per lb., while ton containers range from $2^1/_2$ to 3 ¢ per lb., to which figures it is necessary to add the cost of freight in both directions.

Equipment.—The cost of chlorinating machines varies and depends naturally upon the capacity. Machines with a 10 lb. capacity in 24 hours cost about $750, while machines with a capacity of 700 lb. per 24 hours cost about $3500. While this range is wide, it is more or less uniform between these limits.

Labor.—The cost of labor or attendance and maintenance of chlorinating equipment is relatively small. Very seldom, and even where small quantities of chlorine are used, does this figure exceed $^1/_2$ ¢ per lb. of chlorine used.

Cost for Disinfection.—The amount of chlorine required depends upon the strength of the sewage and the purpose for which it is to be used. Assuming general conditions, it is possible to give some figures which are indicative of the cost.

For disinfection purposes, the requirements may vary from 50 to 90 lb. per million gallons for crude, fine screened and settled sewage, and from 15 to 25 lb. per m. g. for effluents from an activated sludge or trickling filter plant. In addition to this variation, the factor of plant size must be considered. Upon this basis the cost per m. g. for disinfection of crude, fine screened and settled sewage has been estimated to range for plants with average flows under $1^1/_2$ m. g. d., between $1^1/_2$ and $2^1/_2$ m. g. d., and with more than $2^1/_2$ m. g. d., from $4.50 to $7.00, from $3.25 to $4.50, and from $1.75 to $3.25, respectively. For an oxidized sewage or plant effluent, the cost per m. g. would range from $0.50 to $2.50 per m. g. d., depending upon the quantity of sewage treated or chlorine used.

The cost of disinfection at Cleveland during the summer season of 1929, using tank cars at the Westerly Plant and ton containers at the Easterly, amounted to $3.08 and $2.48, respectively, with dosages of 72 and 66 pounds of chlorine per million gallons.

Cost for Odor Control.—The range in cost of chlorination for odor control likewise depends upon local conditions. Experience in this field has been mostly at plants having smaller flows, such as 5 m. g. d. or less. With a range in quantity of chlorine required from 75 to 100 lb. per m. g., applied from 3 to 10 P. M. during 150 days of the year the cost per m. g. will be between $0.50 to $2.50. It is to be appreciated that this figure would be substantially reduced if the chlorine cost is distributed over the sewage flow during the entire year.

Downes of Plainfield advises that odor control during the past summer, when the amount used averaged 98 lb. of chlorine per day, cost $1.42 per m. g. of sewage passed through the disposal works. In 1929 when about 70 lb. per day was used, the cost was $1.02 per m. g. of sewage treated during the chlorination period. Chlorine costs $0.048 per lb. delivered at the plant in 150-lb. cylinders by truck, the same truck returning the empty cylinders free. The sewage flow averaged about 3.3 m. g. d.

During the year 1929, roughly 10,000 lb. of chlorine were employed in stack-gas deodorization at the Milwaukee Sewage Treatment Works at a cost of $3000, this figure being taken from the 1929 Report of the Sewerage Commission.

Cost for Relieving Pooling.—The cost of chlorine for relieving trickling filters from pooling can be estimated upon a per acre basis. However, certain assumptions must then be made which involve the duration of dosage, such as 12 hours during the night at rates of from 20 to 30 p. p. m. chlorine with rates of filtration of 1 to 2 million gallons per acre per day, for six consecutive nights. Such an assumption gives a rate of approximately 1000 lb. of chlorine per acre, which amount might be increased 50 per cent for extreme pooling. Using the above basis the range in cost for filters of less than 15 acres is from $65 to $100 per acre, while with

acreages of from 15 to 25, the cost varies from $45 to $65, and with areas of 25 acres and over, from $25 to $45. The cost of relieving pooling at Lackawanna, N. Y., and Elgin, Ill., are reported at $110.40 and $237.00 per acre, respectively. Apparently these costs were applied to conditions which would be quite liberal if this work were repeated. It is with these ideas that it is thought safe to use the ranges mentioned above.

Cost for Reducing B. O. D.—Aside from the question of what actually happens, the cost of chlorination for inhibiting or actually reducing the oxygen demand of sewage has wide range, and depends upon the quantity of chlorine used and the period during which the application occurs. Upon the basis of applying from 70 to 100 lb. per m. g., during 120 days of the year, the cost range for plants of less than $1^1/_2$ m. g. d. is from $5.50 to $8.50. For plants of from $1^1/_2$ to 3 m. g. d., from $3.75 to $5.50, and for plants with flows more than 3 m. g., from $2.25 to $3.75.

At Flint, Michigan, the effluent from the Imhoff tanks is chlorinated to maintain the oxygen content in the river below the plant, and to correct odor nuisances. Chlorination is practised during the summer only. Costs are not available.

At Middletown, N. Y., prechlorinated settled sewage from continuous sludge-removal tanks is discharged to a stream which flows four miles or thereabouts to a river of adequate volume for dilution. Chlorination is practised during the summer only. Donaldson, of Fuller & McClintock, advises that at Middletown, chlorination cost $2.25 per m. g. in 1930. The chlorine is applied to the tank influent with an average dosage of about 80 lb. per m. g., and is delivered to the plant in 1-ton containers. The sewage flow in this plant averages about $2^1/_4$ m. g. d.

The effluent from the overloaded trickling filters at Columbus, Ohio, is chlorinated to increase the reduction in oxygen demand during the summer months. I am not informed with regard to costs at Flint and Columbus.

Conclusions

Present-day practice demonstrates that chlorination has a definite place in sewage treatment. In recent years the development in this field has been extremely rapid. This same experience occurred in the field of water purification. It should be emphasized, therefore, that chlorination is not a cure-all for all the ills in sewage treatment and, as in the case of water purification, it must be regarded as a valuable adjunct to and not as a replacement for recognized methods and processes of treatment.

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The Digestion of Scum from Preliminary Settling Tanks

BY C. E. KEEFER* AND HERMAN KRATZ**

During recent years investigators have concentrated their efforts to determine the optimum conditions for the digestion of sewage sludge. A review of the literature, however, would indicate that little if any work has been done on the digestion of sewage scum removed from preliminary settling tanks. In a large sewage works the quantity of scum formed may be considerable, and its disposal a matter of importance. A knowledge, therefore, of the environmental factors influencing its digestion is of value. One of the most striking differences between this material and sludge is that the ether-soluble matter in the scum is usually considerably greater, averaging at Baltimore from $2^1/_2$ to 3 times as great.

In order to learn some of the facts regarding scum digestion two series of experiments were conducted in duplicate. Some of the more important questions investigated were the time required to digest the material, the pH value at which the scum would decompose most rapidly, and the quantities of methane and total gas evolved. The results of the investigation indicate that scum collected at Baltimore will digest most rapidly at a pH value of from 7.2 to 8.0 with a total gas production 15 to 20 per cent greater than from sewage sludge. It was also found that digestion was complete within about 35 days.

Method of Conducting Experiment

A quantity of scum was collected from the surface of one of the preliminary settling tanks at the Baltimore sewage works. This material was seeded with digested sludge as indicated in the ratio of two parts by weight of the former to one of the latter on the dry volatile solids basis. This ratio was adopted for comparative purposes as it has been used in previous experiments at Baltimore on sludge digestion. The mixture was placed in twelve 5-gallon bottles, which were divided in two groups of six each. The treatment given each group was the same in order that the results could

CHARACTERISTICS AND QUANTITIES OF SCUM AND DIGESTED SLUDGE USED

	Weight (Wet), Grams	Moisture %	pH	Solids — Total, Grams	Volatile — Weight, Grams	Volatile — %	Ether-Soluble — Weight, Grams	Ether-Soluble Matter % Dry Solids Basis
Scum	1102	49.2	5.2	560	549	98.1	468	83.6
Digested sludge	6612	92.15	7.2	519	275	53.0	60	11.6
Ratio of scum to digested sludge	1:6	...	...	1:0.9	2:1	..	1:0.13	..

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be checked and compared with one another. The sludges in five of the bottles in each group were adjusted at frequent intervals with hydrated lime or a 35 per cent solution of hydrochloric acid in order to maintain pH values of 6.4, 6.8, 7.2, 7.6 and 8.0. No adjustment was made to the pH value of the scum in the sixth bottle, which was used as a control.

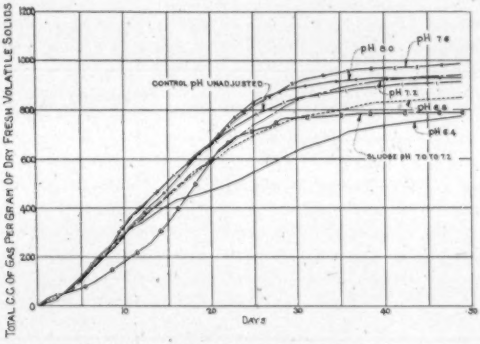


FIG. 1.—Total Gas Production from Scum Digesting at Various pH Values.

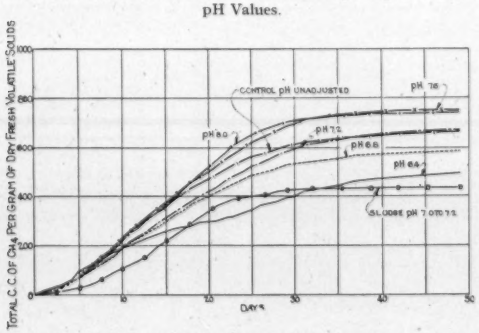


FIG. 2.—Methane Production from Scum Digesting at Various pH Values.

It was considered desirable to compare the rate of digestion of these materials with sludge which had settled in one of the preliminary settling tanks. Sludge about one week old, therefore, was collected and mixed with the same ripe material used to seed the scum and in the same proportions as the materials in the other bottles. This mixture was put in two

bottles, and kept at a pH value of from 7.0 to 7.2. All of the materials were incubated at 28° C. ± 1° for 49 days. Moisture, volatile solids, ether-soluble matter and pH values were determined twice a week. The volume of gas produced was determined daily, and gas analyses were made at frequent intervals. All gas volumes have been reduced to 0° C. at a pressure of 760 mm. of mercury.

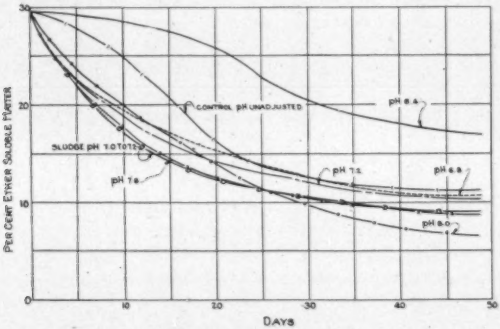


FIG. 3.—Relation of Various pH Values to Reduction in Ether-Soluble Matter of Scum.

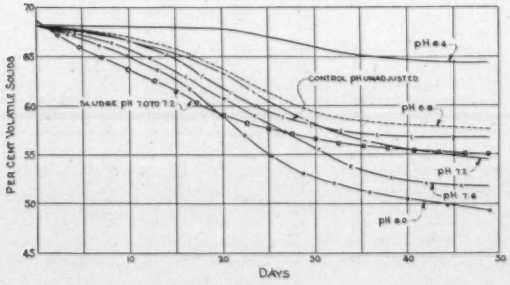


FIG. 4.—Relation of Various pH Values to Reduction in Volatile Solids of Scum.

Results

The results of the experiments are shown graphically in Figures 1 to 4. Figure 1, which shows the total gas production, indicates that when the pH value of the scum was kept between 7.2 and 8.0 the most rapid ebullition of gas resulted. Under these conditions the total gas production

varied from about 900 to 1000 cc. per gram of dry volatile fresh solids, about 15 per cent more than the gas obtained from the raw sludge. Generally speaking gas production was 90 per cent completed within 30 days and entirely so within 40 days.

The scum used as a control, the pH value of which was not adjusted, produced gas at about the same rate as the scum kept at a pH value of 7.2. The pH value of the control was 6.7 at the beginning of the experiment and 7.3 at the end. This rapid ebullition of gas and digestion of scum is unique. When normal sewage sludge, collected at Baltimore, is digested under the same conditions without controlling the reaction and mixed with the same proportions of seeding material, the digestion of the sludge is almost always much slower as indicated by the quantity of gas formed and by the reduction in volatile solids.

The cumulative curves, indicating the total quantities of methane produced, are shown in Figure 2. There was a proportionately greater quantity of methane produced as the pH values were increased from 6.4 to 7.6. For some unknown reason the quantity of methane collected from the sludge was lower than usual.

Volatile matter reduction is shown in Figure 3. The higher the pH value was kept, the greater was the reduction in volatile solids. As indicated in Figure 4, a greater reduction in ether-soluble matter also resulted when high pH values were maintained.

Discussion

Generally speaking the conclusions drawn from small scale laboratory experiments should be made with extreme care. It is believed, however, that the following tentative statement can be made regarding the digestion of scum collected at Baltimore and incubated at 28° C.:

1. Scum digests at least at the same rate, and if anything somewhat more rapidly than sludge.
2. The optimum pH value for rapid digestion is from 7.2 to 8.0.
3. At the above pH values the gas production will vary from about 900 to 1000 cc. of total gas and from about 650 to 750 cc. of methane per gram of fresh dry volatile solids. This volume of gas is greater than that obtained from sludge.
4. Digestion is about 90 per cent complete within 30 days and fully complete within 40 days.
5. Digestion of seeded scum, the reaction of which is uncontrolled, is just about as rapid as when the pH value is adjusted, and much more rapid than seeded sludge, the pH of which is not controlled.

The Baltimore sewage works is under the direction of C. F. Goob, Chief Engineer, and Milton J. Ruark, Sewerage Engineer, with G. K. Armeling, Superintendent.

Trend of Developments in Separate Sludge Digestion*

BY WAYNE A. KIVELL**

The outstanding developments of recent years in sewage treatment have been the activated-sludge process and separate sludge digestion. Separate sludge digestion has been experimented with for many years, beginning with hopper-bottomed settling and digestion tanks. The first improvement was the adaptation of mechanical sludge-removal equipment for settling tanks. Only a few plants of this type were installed, on account of poor results obtained when sludge was digested in open, unheated tanks. Further improvements were made to the system when sludge stirring apparatus was introduced. The first plant of this type was put into operation in August, 1923, at Brownsville, Texas. There followed a number of small plants using mechanical apparatus both for sedimentation and digestion tanks, but it was not until the advent of heated digesters that the process could be said to have arrived. The first complete new plant of this type was installed in December, 1926, at Antigo, Wisconsin. How rapidly the process has spread may be indicated from the fact that there are now approximately 100 plants installed for a designed population of $3^1/_2$ million inhabitants. The largest separate sludge-digestion plant under contract to date is for the City of Toledo, Ohio, designed for a population of 600,000. This paper will briefly discuss developments as applied to sedimentation, digestion and sludge disposal.

Sedimentation

Detention Periods.—Raw sewage, in most instances, is given preliminary treatment by coarse screens for the removal of gross solids such as rags, sticks and garbage, and by grit chambers for the removal of sand and quick-settling inert solids. After coarse screening and grit removal, raw sewage is passed through sedimentation tanks which provide from 1 to 3 hours detention, depending upon the character of sewage and the degree of treatment required. Where sedimentation alone is provided, the detention period is usually 2 hours on average flow. Where sedimentation is followed by activated sludge, detention periods range from 30 minutes to $1^1/_2$ hours. At the Chicago North Side plant 30 minutes is provided on average flow. At this plant, however, waste activated sludge will be delivered to the West Side so there is no necessity for a longer detention period to settle out waste activated sludge. At Grand

* *Presented at Fourth Annual Meeting of the Central States Sewage Works Association, Springfield, Ill., June 9, 1930.*

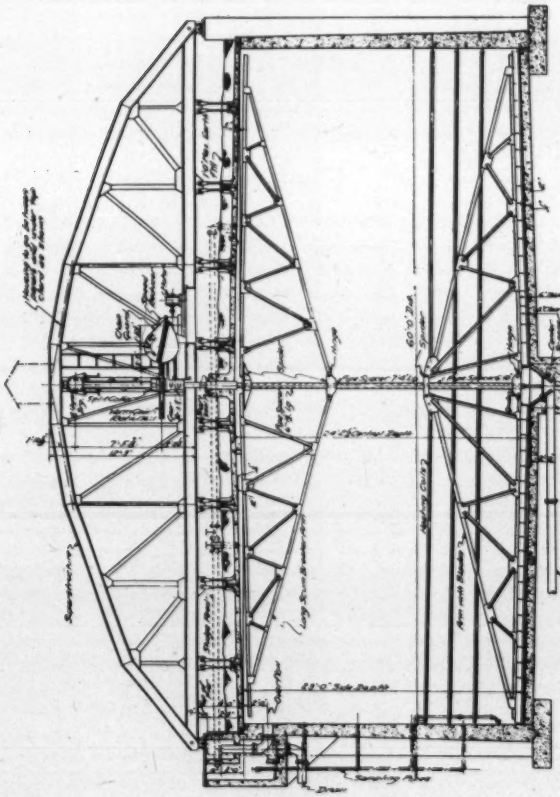
** *Sanitary Engineer, The Dorr Company.*

Rapids, Michigan, $1^1/_2$ hours is being provided. This will give efficient sedimentation during the period that the plant will operate before aeration is added; also, it will provide for sedimentation of waste activated sludge, which will be returned to the raw sewage and resettled. At San Antonio, Texas, 45 minutes detention is provided in the primary sedimentation tanks ahead of aeration.

With the use of more efficient sedimentation units there has been a tendency for engineers to reduce the detention period below that in common practice a few years ago. The Syracuse, New York, plant for example, which provides only rough sedimentation, is designed on the basis of 1-hour detention. Operating results for 2 years give average removal of 56 per cent of suspended solids in 1 hour on a raw sewage carrying 200 p. p. m. suspended solids. At the North Side plant of the Chicago Sanitary District about 26 per cent removal is obtained in 25 minutes with sewage containing 150 p. p. m. suspended solids. Sedimentation efficiency has been increased by the use of mechanical sludge-removal equipment, which will positively remove the sludge and keep the tank in a clean and fresh condition. There is thus no rising sludge, such as occurs in septic tanks, and at times with Imhoff tanks when sludge rises through the slots. More attention has also been given to distribution of sewage through the tank so as to obtain complete displacement and maximum detention period. The use of adjustable weirs where flow can be observed and accurately controlled is a step in the right direction.

Tanks.—All single-story sedimentation tanks are equipped with mechanical sludge-removal apparatus for the collection and thickening of settled sludge. Automatic skimming is also provided for removal of oil, grease and floating solids from the surface of the liquid. In the traction type of clarifier, for instance, a skimming plate is attached to the revolving truss and this serves to sweep the entire tank surface. The scum thus collected is removed at one corner of the tank by an automatic scum sweep and discharge gate, operated by the mechanism. Skimming of sedimentation units eliminates the necessity for any auxiliary grease-removal tanks, such as have been provided in a few installations before the advent of separate sludge digestion. A grease-removal tank of this kind is in operation at the Oklahoma City South Side plant ahead of Imhoff tanks. On account of the long detention periods in settling tanks, more complete flotation of scum, oil and grease is obtained. Settling tanks also present a better appearance where the surface is kept clean.

Influent Channels.—More attention is being given to the design of influent channels to eliminate the old trouble of unequal distribution, settling out of solids and trapping of floating material in the channel itself. Many new installations, such as those at Grand Rapids, Michigan,



Cross Section of Dorr Digester.

Peoria and Rockford, Illinois, are using aerated influent channels similar to those used in activated-sludge plants. It is expected that aeration of the raw sewage will also assist in flotation of oil and grease. Where excess activated sludge is returned to the raw sewage, there may be a beneficial effect on sedimentation due to sweeping action of the activated-sludge floc.

Raw Sludge Removal.—The removal of raw sludge from sedimentation tanks has presented some difficulties in the past. Some plants have been equipped with gravity discharge, others with centrifugal pumps, but most installations have used plunger or diaphragm pumps so connected that raw sludge can be delivered direct from the sedimentation units to the sludge digestion tanks. Experience to date indicates that neither gravity discharge nor centrifugal pumps are satisfactory for this purpose. Centrifugal pumps have recently been replaced by diaphragm pumps at Red Bank, New Jersey, and Fostoria, Ohio. Operators have reported difficulties with gravity sludge-discharge systems in other plants on account of stoppages and inability to maintain thick sludge. With gravity discharge, using gate valves or swivel pipes, the sludge either thickens and the flow stops, or if the rate of withdrawal is increased, the sludge thins out and too much water is withdrawn.

Many operating difficulties have been eliminated by the installation of finer openings for bar screens. These are now commonly $^3/_4$ inch clear for large sewer systems and 1 inch clear for small plants treating domestic sewage. More efficient grit chambers will prevent accumulations of sand and heavy grit in sludge lines.

With the advent of heated tanks, special attention is now being given to concentration and thickening of raw sludge before pumping. If careful attention is given to pumping operations average sludge moistures need not exceed 90 per cent. At Sioux Falls, South Dakota, the average solids content of a mixture of municipal and packing-house sludge, for 2-hour pumping periods, is 10 to 15 per cent. Salem, Ohio, is removing sludge twice a day at 10-minute intervals, beginning at 20 per cent solids and discontinuing when sludge thins out to 10 per cent. This is a mixture of raw and activated sludge.

Scum.—The disposal of scum collected from sedimentation units presents a problem because of its high liquid content and slimy character. At Grand Rapids scum will be drawn by gravity to pits for burial. At San Antonio scum will be pumped to a separation tank located in the bar-screen and incinerator building, and after the oil and grease has separated it will be drawn to a gas-fired incinerator and destroyed along with bar screenings. This seems to be the most sanitary method of disposal, although more experience is needed in the actual operation of such a system.

Digestion of Sludge

Raw sludge collected from primary sedimentation tanks, waste activated sludge from the aeration process and humus sludge from clarifiers following trickling filters, are being digested in gas-tight concrete tanks which are insulated, heated and provided with gas collectors. Only concrete tanks have been used for this purpose, although in a few instances steel or wooden covers have been provided. Special attention is being given to the mechanical separation of end products of digestion and for this purpose mechanical stirring devices are most widely used. A few plants, particularly in Europe, are equipped to agitate the sludge by recirculation with pumps. The cost of digestion in many cases has been greatly reduced from that previously required for Imhoff tanks, because of shallow excavation and greatly reduced volume.

Gas Collection System.—Gas is collected under steel domes constructed in tight covers and is forced out by building up necessary pressure within the domes. It can thus be piped to any part of the plant, where it can be utilized for heating of digestion tanks, buildings or other uses. In some of the early installations very little attention was given to proper insulation or draining of these gas lines, with the result that some trouble was encountered with freezing in the winter time. In more recent installations gas piping is laid within the roof of the tank and protected in the ground until gas is delivered to the heating station. The collection system is usually provided with a condensate trap for removing water, meters for accurate measurement of gas and suitable regulating and pressure-relief devices ahead of boilers or other equipment in which gas is utilized. Gas pressures of 5 to 6 inches of water are required at the digesters to give suitable pressure at the boilers. The maximum pressure that can be built up at the digestion tanks will depend on weight of the roof system. With heavy concrete roof systems insulated with earth fill or cinders, such as those installed at Toledo, Ohio, and Peoria and Aurora, Illinois, it is possible to build up pressures of 10 to 15 inches of water. With light steel covers the maximum gas pressure might prove to be insufficient, especially in large plants.

Heating Systems.—Gas is being burned under low-pressure hot water boilers operating at 3 inches water pressure. Digestion tanks are thus heated by hot water circulated through coils placed around the inside periphery of the tank. In some of the early installations headers were used connecting three or four single coils usually of $1^1/_4$-inch diameter pipe. The trouble with this system was that unequal circulation was secured through the individual coils; also, the heat was distributed at a single level throughout the tank. As a result of considerable operating experience engineers are now using spiral coils, which distribute the heat

from top to bottom as well as around the entire side walls of the tank. Cross connections are also made inside the heating station so that hot water can enter either at the bottom or top of the tank. If the tank contains only a small amount of sludge hot water is introduced at the bottom where it will do the most good. After the digester becomes well filled, the flow can be reversed so that heat is applied to the more active zone near the top, consequently less heat is lost in the digested sludge at the bottom.

For the first installations very little information was available on the coefficient of radiation of hot-water coils submerged in sludge. The amount of heating surface provided was too small. This is well indicated by the temperature of return circulating water as compared with tank temperatures. At Springfield, Missouri, for example, three $1^1/_4$-inch diameter coils were installed in a digestion tank 65 ft. in diameter. After the tank was in normal operation the temperature of the returned water stabilized at 160° to 180° F., with a digester temperature of only 80° F. This indicates insufficient radiation surface. The present tendency is to be liberal in amount of heating coils used. A coefficient of radiation of 30 B. T. U. per square foot per hour per degree mean temperature difference appears to be satisfactory.

Agitation.—Concentration of solids is of primary importance in heated digestion tanks. More than three-fourths of the volume of fresh sludge must be decanted as supernatant liquor. Solids must be freed from the sludge liquor, and end products such as gas, supernatant liquor and digested sludge taken off at definite locations. In most plants this hydro-separation is being accomplished by slow stirring, although attempts have been made to secure results by recirculation of sludge with pumps or by vertical screw impellers located within the tanks. Slow stirring permits the sludge to classify, with the digested sludge, which runs higher in ash content, slowly working to the bottom, whereas raw sludge, which is higher in volatile matter, remains near the sludge line. The supernatant liquor remains clear with any reasonable rate of feeding raw sludge and there is very little tendency to lose suspended solids in the discharged liquor. Recirculation of sludge from bottom to top of tank appears to cause bulking. In conducting some test work at Sioux Falls, South Dakota, digested sludge was pumped from two digesters into a third unit. It was found that after one week the top sludge had not yet settled to the same density it occupied in its original position. At Flint, Michigan, it was found that recirculation of Imhoff sludge by air lifts to reduce foaming caused bulking. The operator concluded that one or two hours circulation once a month for each hopper gave best results in reducing scum and promoting digestion without bulking of sludge. Further information on this procedure will be of interest.

Raw Sludge Feed.—Raw sludge is commonly admitted into the top of the tank and an effort is made to distribute it evenly over the entire area. It is preferable to admit it continuously at low rates rather than to introduce large volumes at infrequent intervals. The outstanding example of batch feeding is at Baltimore, where unfavorable results have been obtained because of the necessity of hand-sludging large settling tanks and delivering a large volume of raw sludge to open digesters. The digestion balance of the tank is upset by this method. Where secondary treatment is required, many new installations have used a combination of activated-sludge and separate sludge digestion. Examples of this are at Salem, Ohio, Grand Rapids, Michigan, Peoria, Illinois, and San Antonio, Texas. Each plant is laid out so that excess activated sludge can be wasted continuously to the raw sewage, where it can be resettled and mixed with raw sludge. The consolidated sludge is then pumped more or less continuously to the digestion tanks. During early operation of the Salem plant waste activated sludge was delivered in batches to the primary settling tanks, with the result that bulking developed in the sludge and made necessary the pumping of large quantities of dilute sludge to the digester. The high rate of pumping disturbed the digestion process and caused bulking of the supernatant liquor. The digester overflow returned to the raw sewage was in reality a thin sludge. The aeration process was upset by this liquor. This method of operation was soon discontinued and activated sludge was wasted to a small storage tank. After minor revisions were made in the piping waste activated sludge was returned to the raw sewage continuously; since this method of operation has been adopted normal digestion has been established and excellent results are being obtained. Unexpectedly good results have been obtained by consolidating the raw and activated sludge. It was at first anticipated that the resulting moisture content would be rather high, whereas on the contrary, average solids content as pumped is as low as obtained on raw sludge alone. Waste activated sludge seems to have very little effect on the moisture content of raw sludge. At Pomona, California, where Imhoff tanks are used for preliminary sedimentation and sludge digestion, waste activated sludge was first returned to the Imhoff tank hoppers. The delivery of such a volume caused an equal displacement of partially digested sludge up through the sedimentation slots and this apparently upset the aeration process. Activated sludge is now wasted directly to the raw sewage and resettled with good results. There is enough operating experience to date to establish thoroughly the process of wasting excess activated sludge to the influent of the primary settling tanks.

Supernatant Liquor.—The water that separates from raw sludge fed to digestion tanks must be decanted as supernatant liquor, although the

total volume of this liquor seldom amounts to more than one quarter of one per cent of the raw sewage flow. If the liquor is accumulated for several days and then discharged in a few hours the high rate of flow tends to carry over more suspended solids than would otherwise be lost if the same volume were discharged continuously. In a well-operated digestion tank the suspended solids rarely exceed 600 to 800 p. p. m. and these will resettle in 15 to 30 minutes. It is impossible to secure an absolutely clear overflow as there is always a small amount of solids in suspension in the supernatant liquor due to rising gas bubbles, to which are attached small particles of sludge. Dissolved solids are high, ordinarily 1200 to 1500 parts per million.

Gas.—Interesting data are now becoming available on gas production at several plants where accurate measuring devices are installed. With the new 1930 census figures available, it will be possible to estimate gas production on a per capita basis, although long-time records with more confirming data are needed to estimate gas production from actual weight of volatile matter delivered to digestion tanks. Records to date secured from plants at Aurora, Illinois, Antigo, Waukesha and Fond du Lac, Wisconsin, and Springfield, Missouri, indicate production of 0.75 cu. ft. per capita per day for solids from plain sedimentation tanks. Approximately 1 cu. ft. per capita per day is produced at Salem, Ohio, from combined raw and activated sludge.

Gas is being used primarily for heating sludge-digestion tanks, and additional gas is available at Aurora, Illinois, for heating the main buildings during cold weather. Fort Worth and San Antonio, Texas, successfully utilize gas for incineration of screenings.

Preliminary calculations indicate that there is a possibility of securing sufficient power from sludge gas to operate aeration tanks of the activated-sludge process. All gas would be used for power development by installing gas engines directly connected to air blowers. The digestion tanks would be heated by circulating the cooling water of the gas engines through heating coils in the digestion tanks. There is apparently enough waste heat in the jacket water of the gas engines to take care of the requirements of digestion tanks under normal conditions, but if further heat is required, it could be obtained by installing economizers on the exhausts from the engines. Such a system was laid out for Fort Worth, Texas, but installation has been delayed until the city has sufficient operating records to prove and justify the installation. Whether there could be any economy in a power development of this kind has not been established, although the possibilities are inviting.

Scum.—When plain unheated digestion tanks were used, it was not uncommon for 60 per cent of the sludge to accumulate at the top of the tank in the form of scum, which might become so dense and heavy that a

man could walk across the surface. Much of this scum formation was eliminated in the early installations of separate digesters by the use of stirring devices. Flotation of sludge was reduced by slow stirring of a mechanism in the bottom of the tank, and what scum did form was further broken up by the use of a scum breaker at the surface. Installations of this type were uniformly successful, although it was not until the advent of heated tanks that scum formation practically disappeared. A notable example of results, to be obtained by a combination of slow stirring and heating, is found in the separate sludge-digestion plant now in operation at Sioux Falls, South Dakota. This plant receives a mixed sewage from a city population of approximately 35,000 inhabitants, contributing 2.4 million gallons per day and industrial waste from a large meat-packing plant contributing 1.9 million gallons per day. The packing-house sewage receives preliminary treatment by fine screening and 30 minutes detention in a clarifier for grease removal. All sludge settled out in the grease-removal tanks was originally delivered to the city digesters. Before the installation of the heating system, scum accumulated to such a depth that it was necessary to discontinue delivery of packing-house sludge. This sludge contained a great amount of paunch contents and was the principal cause of scum formation. After the installation of a heating system in the digestion tanks the city again attempted to handle packing-house sludge. A test run is being made on one digestion tank, which has now (June, 1930) been operating on a mixture of city and packing-house sludge for five months with good success. The scum noted in this tank is but little more than is produced in the other two tanks operating on municipal sludge alone.

Practically all digestion tanks are provided with permanent scum drains so that any accumulation of scum inside the gas domes can be drawn off by gravity to the sludge beds. Almost no sludge is found in these domes, the scum consisting entirely of fibrous material, such as leaves, sticks, matches, and seeds.

Digested Sludge.—Heated digested sludge is jet black, is gritty and granular in character, drains readily and has very little odor except that of tar. Solids concentrations are quite uniform from plants treating sewage of the same character. Solids content of waste sludge delivered to drying beds is from 10 to 14 per cent. The moisture content of sludge seems to depend mostly on the character of raw sludge being digested. Water depth of the digestion tanks has very little, if any, effect on the concentration of sludge. Analyses of the sludge in a number of tanks at one-foot intervals indicate a slight compression due to depth of sludge. This increase in solids content will run from $^1/_2$ to 1 per cent. Recent analyses of the sludge in three digesters at Sioux Falls show solids concentrations of 10.5 to 12 per cent and ash contents of 54.5 to 58 per cent.

This indicates a volatile matter reduction of 70 to 72 per cent, based on an ash content of 28 per cent in the raw sludge. With the digestion of sludge received from large combined sewer systems, such as at Chicago, Illinois, where raw sludge runs high in ash content (45 per cent), it is anticipated that solids concentrations of 13 to 15 per cent may be obtained.

Disposal of Sludge

Most new plants include sand drying beds, either open air or glass covered. The drying time on open beds is dependent on weather conditions so that liberal areas must be provided. Instances of only three cleanings per year are on record although five to seven cleanings are the average experience with open beds. The use of glass-covered sludge beds eliminates wet weather hazards in summer and makes it possible to obtain more or less drying during winter months. Glass-covered sludge beds are gaining favor where separate sludge digestion is used, as capacity of digestion tanks or sludge-storage tanks can be reduced where part of the sludge can be dried during winter months. Probably the largest glass-covered sludge beds are now under contract at Toledo, Ohio, where 3.6 acres will be used.

Lagooning.—There is a possibility that in the future more digested sludge will be pumped directly to lagoons for final disposal than is being done at the present time. The sludge beds at Mason City, Iowa, have never been used and all sludge produced in the Imhoff tanks has been run directly to borrow pits formed adjacent to the Imhoff tanks at the time of construction. Sludge has accumulated to a depth of several feet and no fly or odor nuisance has been reported from the operation of this lagoon. The sludge beds at Fort Worth, Texas, constructed in 1924, were never used. Sludge from the Imhoff tanks has been pumped directly over the levee to a disposal area between the plant and river. The new treatment plant at San Antonio, Texas, will dispose of digested sludge by pumping directly to lagoons adjacent to the plant. Conditions in this southern climate are most favorable for lagooning on account of continued warm weather and small amount of rainfall.

Filtration.—Experiments are now being conducted on the mechanical filtration of digested sludge. Digested sludge is taken directly from heated digestion tanks, conditioned, filtered and removed to dumps or dried and sold as low-grade fertilizer. If this process should be economically successful it would permit the elimination of 4 to 5 months storage capacity for digested sludge, the elimination of all sludge beds, a reduction in amount and size of equipment required for transporting dried sludge and possibly a reduction in total labor required to handle digested sludge.

Concentration and Distribution of Sewage Solids During Digestion*

BY WILLEM RUDOLFS AND I. O. LACY

Solids entering a digestion tank tend to compact and concentrate. If this compacting were not disturbed it would be a simple matter to predict the sludge concentration after a given time. However, during the digestion of sewage solids a number of physical changes occur, the results of which may appear as "thin" sludge, and under aggravated conditions, as "foaming."

The phenomena observed in the digesting mass are principally a separation of liquid and solids and the dispersion and movement of solids throughout the liquid. Simultaneously, changes in the reaction of the medium occur, the surface tension changes and entrained gas bubbles rise through the mass, expanding with their upward rise and usually bursting at the surface. Sometimes the small gas bubbles do not break but remain in a thin, slimy mass, forming a foam.

It was deemed of interest to conduct a series of experiments which would enable us to follow the movement of the sludge particles, observe the compacting and follow the changes from day to day under different conditions. One set of experiments was conducted with ripe sludge and another with fresh solids, in order to observe the concentration of the material. In another set of experiments profuse "foaming" was produced by improper seeding of the mixtures. After foaming had been produced and the material began to boil over the edges of the container, the reaction of the mass was changed by the introduction of hydrated lime. In order to make the study more comprehensive an attempt was made to determine the effect, if any, of the depth of the tank on foaming and upon the density of the sludge produced.

Still another set of experiments was conducted in vessels of different depths, with properly seeded fresh solids. The last two sets of experiments were identical except for the difference in seeding, which resulted in differences of behavior of the material. Finally, a set of experiments was conducted in which daily quantities of fresh solids were added to ripe sludge.

I. Concentration of Ripe Sludge and Fresh Solids

Studies on the settling and compacting of ripe sludge and fresh solids were conducted in containers 9 feet high. The containers were made of glass, graduated at intervals, so that the movement of the sludge layers could be observed.

* *Journal Series Paper of the New Jersey Agricultural Experiment Station, New Brunswick, N. J., Dept. Sewage Research.*

The cylinders were filled with ripe sludge obtained from a separate sludge-digestion tank, and the fresh solids from a settling tank. Compacting was measured at hourly intervals during the day. The experiments were conducted over a period of 96 hours. Analyses of the sludge were made at the beginning and end of the experiment. The results of the analyses were as follows:

	Beginning %	End %	Increase %
Ripe sludge	5.24	9.86	47
Fresh solids	8.00	11.93	33

The reduction in volume of the sludge is shown in Figure 1. The fresh solids settled somewhat more slowly than the ripe sludge. This may be due to the fact that the fresh solids were collected at the time when they were pumped from the settling basin into the digesters. This procedure is followed daily, therefore the results should be comparable to ordinary practice. Another factor which would influence the volume reduction is that the concentration of the sludge was initially less than that of the fresh solids. Experiments with different concentrations of sludges show that the percentage compacting depends partly on the original density of the sludge. Averaging results of a number of experiments with fresh solids and ripe sludge of different densities it appears that the fresh solids settle during the first 24 hours somewhat more rapidly than the ripe sludge. After 72 hours the percentage compacting is similar. The following are the average percentages of compacting for fresh solids and ripe sludge.

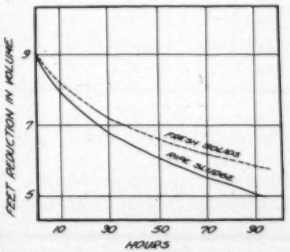


FIG. 1.—Reduction in Volume of Fresh Solids and Ripe Sludge in a Given Time.

Hours	Fresh Solids %	Ripe Sludge %
8	8	5
16	13	9
24	17	13
48	25	22
72	29	29
96	33	33
120	34	36

After 72 hours the fresh solids began to produce small quantities of gas. The small gas bubbles were imbedded in the sludge, causing it to expand. This expansion was quite noticeable after 120 hours. It would seem

that sludge violently stirred daily would have a tendency to be thinner than sludge compacting more or less quiescently, since in no case was maximum compacting found after as short a period as 24 hours.

II. Improperly Seeded Sludge

In batch digestion it has been the practice, producing apparently good results, to mix fresh solids with sufficient ripe sludge. In this experiment the fresh solids and ripe sludge, after being collected separately, were mixed as described below.

Methods.—An improperly seeded mixture was made by mixing three parts of volatile matter in fresh solids with one part of volatile matter in ripe sludge. The mixtures were introduced in calibrated glass containers 3, 6 and 9 feet high, respectively. Each container was connected with a separate gas-collecting apparatus, consisting of calibrated glass tubes connected with inverted carboys filled with gas-saturated water.

A daily record was kept of the amounts of gas produced, the movements of the sludge through the liquid and the volume of scum formed, while the volume of liquid which separated the sludge and scum was measured. Temperature records were kept.

Chemical analyses consisted of determinations of solids and ash at the beginning and end of the experiment. A few times small quantities of liquid were withdrawn to determine the reaction of the materials. On the third day of the experiment, when foaming was very pronounced, calculated quantities of hydrated lime were added to make the masses slightly alkaline and to stop foaming. The experiment was continued for 95 days.

In order to obtain the sludge density throughout the period at any given time it was assumed that the gas evolved was in proportion to the quantities of volatile matter destroyed. Assuming that this is correct in these substances, then:

$$\text{S present } (n^{\text{th}} \text{ day}) - \left(\frac{\text{cum. G/gm. V. M. added } n^{\text{th}} \text{ day}}{\text{tot. cum. G/gm. V. M. added}} \times \text{tot. V. M. lost}\right) = \text{gm. S remaining}$$

Then:

$$\frac{\text{Gm. solids remaining}}{\text{Volume occupied by sludge}} = \text{concentration of sludge.}$$

S = total solids.
G = gas.
V. M. = volatile matter.

Results.—The analytical results obtained are given in Table I. The differences in chemical results are very small; solids reduction in the different containers ranged from 36.3 to 39.0 per cent. From a chemical standpoint the mixtures might be considered as approximately the same.

TABLE I

CHEMICAL RESULTS WITH IMPROPERLY SEEDED MIXTURES

	3 Ft.		6 Ft.		9 Ft.	
	Begin.	End.	Begin.	End.	Begin.	End.
Dry solids, per cent	7.3	4.9	6.95	4.8	6.8	4.7
Dry solids, grams	146	93	278	180	408	249
Reduction, per cent	..	36.3	...	37.5	...	39.0
Volatile matter, per cent	67	53.2	68	49.5	67	47.8
Volatile matter, grams	97.6	49.5	188	84.8	274	119
pH	6.0	7.2	6.0	7.3	6.0	7.4
Reduction, per cent	..	49.3	...	55.0	...	56.0

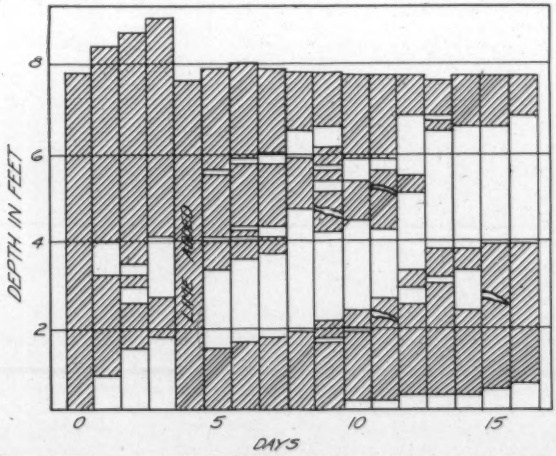


FIG. 2.—Movement of Solids during First 16 Days of Digestion of Improperly Seeded Solids.

Since the behavior of the three sets was also rather similar the data obtained on solids movement and gas production in the 9 ft. tube are used for plotting the results. Gas production from this experiment was as follows:

Total gas produced	166.5 liters
Gas per gram solids	408 cc.
Gas per gram volatile matter	607 cc.
Gas per gram volatile matter destroyed	1072 cc.

The movement of the solids is graphically presented in Figures 2 and 3. For convenience a section of the experiment covering 15 days is shown in

Figure 2 and the total period of 95 days in Figure 3. The shaded areas designate the distribution of the solids in the container, whereas the blank spaces indicate clear liquid, unless otherwise noted.

After the mixtures had been introduced into the containers the mass began to gasify almost immediately and started to expand, due to the entrained gas bubbles. Expansion continued and a grayish mass began to appear at the top. After three days the mass was working vigorously and foaming was very pronounced. The mass had expanded in this short time more than 16 per cent in volume. At the time of foaming the masses were light gray in color, appeared to be very porous and loose, contained numerous very small gas bubbles and gave off strong putrefactive odors.

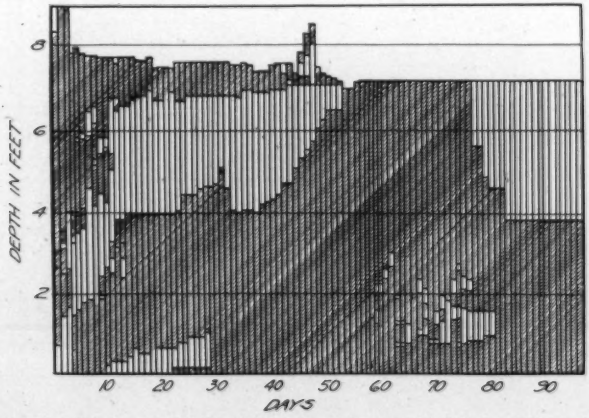


FIG. 3.—Movement of Solids of Improperly Seeded Solids during Digestion; Sludge Column 9 Feet High.

At this time the pH value was 5.8. Sufficient quantities of hydrated lime were added to adjust the pH value to 7.3. The lime was added to a volume of liquid drawn from the bottom of the containers and after mixing was returned to the top of the solids. Action was almost immediate, the lime mixture penetrated to the bottom of the mass in a very few minutes without any stirring. While the liquid lime mixture was added a strong odor of ammonia was noticed. The one addition of lime was sufficient to stop foaming. After liming the mixture a part of the sludge mass rose from the bottom, due to the fact that the biological activities were stimulated and the gas bubbles buoyed up the sludge particles at a

more rapid rate than they could settle. With time the gas production increased and instead of the many "pin-point" gas bubbles they became larger in size, escaping from the liquid with greater ease. After about 35 days gas formation increased rapidly with the result that the sludge particles became more and more distributed throughout the liquid. The rapid and continuous rise of the gas bubbles agitated the masses to such an extent that after 55 days the containers were filled with thin sludge.

As time passed the light gray color of the sludge mass changed and became increasingly darker until finally the well-known blackish blue color was present. Gradually the liquid portion changed from a grayish to a yellowish color. The grayish sludge particles settled and a yellowish color remained, probably due to the humic acids present in the liquid, until finally the liquid portions began to clear up, leaving a fairly transparent supernatant liquid.

Discussion of Results.—Due to the long duration of the experiment a loss in the moisture content occurred. Although the vessels were kept closed and the only outlets were those attached to the gas holders, the loss of moisture must be accounted for by evaporation. Although the surface area of the three vessels was the same and only the depths varied, the greatest loss of moisture was from the deepest containers. Not only the volume of moisture lost from the deepest container was greater, but also the proportionate or percentage loss was greater, with the smallest loss in the shallowest vessel. The differences are explained by the fact that with equal surface areas the surface of the deepest vessel was broken more frequently by the greater release of gas bubbles, since a greater amount of gas was produced. Probably due to this more vigorous and more frequent stirring action of the released gas bubbles, the surface of the deepest vessel was free from scum before the others while the medium high container was free from scum before the shallowest container. This also results in greater evaporation. If this experiment can be taken as an indication, it would seem that the deeper the container the smaller the amount of scum, even with increased volumes of sludge.

From Figure 2 it can be seen that the largest portion of the solids was floating during the first ten days. After liming, the amount of sludge near the bottom began to increase. With the increase of material at the bottom the "scum" layer decreased until after the fortieth day a small, what might be considered as a true, "scum" layer was left, under which gas started to accumulate. Gasification became so rapid that the porosity of the scum layer could not accommodate the flow, so that the gas collected under it, forcing the scum layer upward. Similar phenomena have been observed in gas vents of tanks, and punching holes through the scum releases the gas, with the result that the scum blanket settles.

The experiments were conducted in the laboratory and subject to changes

in temperature. The maximum and minimum temperatures were observed and the mean temperatures are graphically shown, together with the daily gas production, in Figure 4. Small daily fluctuations in gas production are reflected in the change in temperature.

The solids concentration varied throughout the digestion period (Figure 5). After the mixtures were limed the sludge concentration increased continuously to a maximum of 13 per cent solids. Gas production during this time was comparatively small. Gradually the sludge concentration became less so that the whole container was filled with a thin sludge and the concentration amounted to less than 6 per cent. The decrease in sludge concentration coincided with the increase in gas production. During the period of the 45th to the 75th day, when over 60

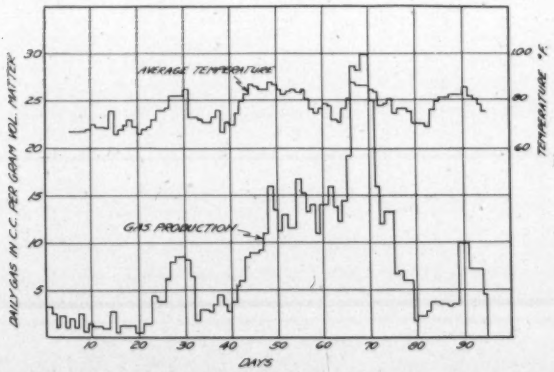


FIG. 4.—Average Temperature and Daily Gas Production of Improperly Seeded Solids.

per cent of the total gas was produced, the sludge concentration remained low. During the digestion period from the 60th to the 80th day the sludge column broke up. The liquid between the various sludge portions was rather clear, in comparison with the degree of transparency previously reached by the supernatant liquid. It was obvious that the sludge portions nearest to the bottom were further advanced in decomposition than the portions nearer to the top. There was a definite segregation of sludge particles, those with less specific gravity and greater volatile matter content rising under the influence of the buoyant action of the gas bubbles.

As soon as the rather copious stream of gas bubbles diminished the sludge began to concentrate rapidly. Within a few days the density

increased from 5.7 to 9.5 per cent. This increase in density was clearly due to the compacting of the sludge, which was undisturbed by gas bubbles, similar to the first 20 days of the experiment. The material required a much longer time to concentrate than the properly seeded mixtures, but when left standing for over 8 months the concentration reached about 18 per cent. It is evident, therefore, that sludge concentration is the result of quiescent compacting and that time under such conditions is an important factor. In continuously operated tanks with improperly seeded mixtures the production of a thick sludge would be nearly impossible.

When the sludge column started to compact, very coarse material, like seeds, mash, etc., was at the bottom. This material is more difficult to digest, but due to its specific gravity settles quickly. Material which

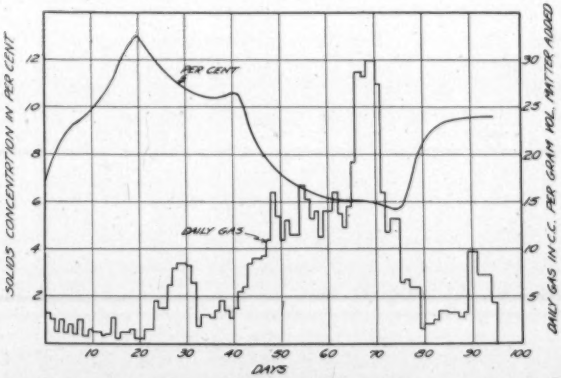


FIG. 5.—Relation between Solids Concentration and Gas Production during Digestion of Improperly Seeded Solids.

decomposed rather rapidly (so far as it was able to digest) settled next. This was borne out by the fact that the color of the liquor at the top was darker than that occurring in the liquor between the breaks of the sludge column. Finally, the bulk of the decomposing mixtures settled, forming a granular mass with a black color.

An attempt was made to determine whether the height of the column affected the density of the sludge. Analyses of the sludge portion of the materials after 95 days showed that the solids contents were 9.5, 9.6 and 9.2 per cent, respectively, for the 3, 6 and 9 ft. columns. The results for these mixtures were so nearly alike that it is safe to assume that the height of the column had practically no effect.

Summary.—Foaming was produced by improper seeding of fresh solids. The foaming was overcome by adding hydrated lime to the liquor of the mixtures, causing sludge to settle. The improper seeding affected the reaction of the medium, its surface tension and viscosity. Small gas bubbles carried small particles of sludge to the top at a more rapid rate than they could settle. The small gas bubbles did not coalesce, but remained imbedded in the thin, viscous mass, producing a foam. Addition of lime changed the reaction of the medium, its surface tension and its viscosity had an apparent "cutting" action on the gas bubbles.

Solids moving downward in the process of settling were buoyed up by the gas at such a rapid rate that solids concentration was lowest when the rate of gas production was highest.

Improperly seeded mixtures, as used in this experiment require about three times as long to digest as properly seeded mixtures, and create undesirable disturbances, with resultant nuisances.

Under the conditions of the experiment the height of the column of sludge and liquid had no appreciable effect on the resultant sludge density.

III. Properly Seeded Fresh Solids

A properly seeded mixture of ripe sludge and fresh solids was made by mixing 2 parts of fresh solids with 1 part of ripe sludge, on a volatile matter basis, or roughly a mixture of 1 to 1 on a dry solids basis. The mixtures were introduced in vessels similar to those used for the experiments with improperly seeded mixtures, namely, containers which would hold sludge columns 3, 6 and 9 ft. high. The ripe sludge and fresh solids were analyzed, with the following results:

	Ripe	Fresh
Solids, per cent	5.5	4.8
Ash, per cent	48.8	22.6
pH	7.3	6.2

Gas production was measured daily and the movement of sludge was recorded and scum formation measured daily.

The chemical results obtained on the mixtures at the beginning and end of the experiment are given in Table II.

TABLE II

CHEMICAL ANALYSES OF PROPERLY SEEDED MIXTURES

	3 Ft.		6 Ft.		9 Ft.	
	Begin.	End.	Begin.	End.	Begin.	End.
Dry solids, per cent	4.84	3.6	4.84	3.8	4.84	3.5
Dry solids, grams	97	70.5	194	148	290	207
Reduction, per cent		27.4		24.0		28.5
Dry volatile matter, per cent	63.8	57.0	63.8	54.0	63.8	57.5
Dry volatile matter, grams	62	40	124	80	186	119
Reduction, per cent		35.5		35.5		35.7

Discussion of Results.—The reduction of volatile matter in the mixtures was from 35.5 to 35.8 per cent. It might be assumed, however, that little if any of the volatile matter in the ripe sludge was destroyed, because the ripe sludge was thoroughly digested. Assuming no change in the ripe sludge the reduction in solids and volatile matter added was as given in Table III.

TABLE III

REDUCTION OF FRESH SOLIDS

	3 Ft.	6 Ft.	9 Ft.
Solids added, grams	54.3	108.6	163.0
Solids destroyed, grams	26.5	50.6	83.4
Solids reduction, per cent	48.5	46.7	51.0
Volatile matter added, grams	42	83.9	126
Volatile matter reduction, per cent	63	61	66

The reduction in solids and volatile matter added indicate that the material was well digested after the period of 28 days and that there were practically no differences between the materials in the three different containers.

Gas productions from the three mixtures were as follows:

	3 Ft.	6 Ft.	9 Ft.
Total gas produced in liters	31.7	64.8	97.9
Gas per gram solids added, cc.	583	597	600
Gas per gram volatile matter added, cc.	756	772	776
Gas per gram volatile matter destroyed, cc.	1195	1280	1175

The amount of gas produced per gram of solids added was practically the same from the three containers, but in comparison considerably higher than from the improperly seeded mixtures. These amounts of gas were produced in a period of 28 days, as compared with a period of 95 days for the improperly seeded mixtures. The volumes of gas produced per gram of volatile matter destroyed from the properly seeded mixtures was also higher than from the improperly seeded mixtures.

Gas production per gram of volatile matter, solids concentration and average temperatures are shown in Figure 6 for the highest column. Results for the other columns were quite similar.

A comparison of results obtained from the improperly seeded mixtures with those under discussion shows some differences and some similarities. During the first few days the sludge concentration remained fairly constant; there was some separation of solids, but not so great as with the improperly seeded mixtures. After the first few days the solids concentration increased rapidly. In spite of the fact that gas production decreased somewhat, the sludge density decreased. The greatest decrease in sludge density occurred during the period of greatest gasification. With the de-

cline in the rate of gasification the solids concentration increased until a maximum of 6.8 per cent was reached.

The color of the liquid layers between the very small amounts of scum and sludge at the bottom became rapidly darker. The effect of the rapid gasification could be noticed for several days after the peak had been reached, as indicated by the comparatively slow rise in solids concentration. This is no doubt due to the fact that the disintegrated and partially digested mass had a specific gravity lower than the fresh solids or ripe sludge alone. It also checks up with the difference in the rate of settling between fresh solids and ripe sludge, previously discussed.

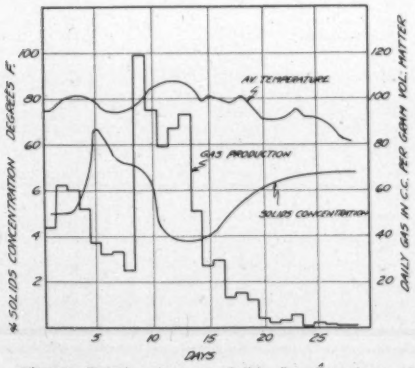


Fig. 6.—Relation between Solids Concentration and Gas Production during Digestion of Properly Seeded Solids.

During the period covered by the first several days the scum layer seemed to be made up of two distinct types; the top portion was soapy, heavily laden with small gas bubbles, while the bottom portion had a pasty appearance. Differences in supernatant liquid and sludge layers could also be noticed. The tendency toward segregation was pronounced.

The sludge concentration in the experiments with properly seeded mixtures was in all instances less than that of the improperly seeded mixtures. However, the sludges at the end of the experiment held about the same relation:

	Average Beginning	Average Ending	Ratio
Improperly seeded	7.0	9.4	1:1.34
Properly seeded	4.85	6.8	1:1.40

The ratio of compacting was therefore about the same, in spite of the fact that the improperly seeded mixtures required 95 days and the properly seeded mixtures 28 days. The time of settling after the peak of gasification had passed was about the same in both instances. It appears, therefore, that the concentration of the final sludge depends upon the original concentration of the material and upon the length of time of settling. The density of the sludge during digestion depends upon the quantity of fresh solids added and upon the rate of biological activities, or in other words the more rapidly digestion takes place the more gas is evolved in a given time, causing greater disturbances and distribution of solids throughout the liquid, with a resultant thinner sludge. With improperly seeded material the time required for digestion is greater and also the time required for compacting of the sludge.

Summary

Properly seeded fresh solids were digested in containers 3, 6 and 9 ft. high. There was practically no difference in solids reduction and the gas production per gram of volatile matter was nearly alike in all containers. In comparison with improperly seeded solids, gas production was greater and the time required for digestion only one-third. The ratio of concentration of the final sludge was in all instances the same, either with properly seeded solids or with improperly seeded material, but the time required for compacting was greater with improperly seeded solids. The concentration of the final sludge depends upon the density of the initial sludge and upon the time of storage. The height of the liquid or sludge column had no effect upon the density of the sludge, nor upon the rate of concentration.

Sewage Works Operation

The Status of Sewage Treatment in Germany

By Dr.-Ing. A. Heilmann*

Translated by F. W. Mohlman

The technique of sewage disposal has undergone marked improvement in Germany since the War. New processes were developed in England and in the United States during the War, and these were investigated in Germany after its termination. Economic necessity compelled consideration of the recovery of all possible materials of value. Attention was directly toward the utilization of all wastes, particularly solid and liquid municipal wastes. Sewage and sewage sludge were investigated with particular care. A marked impetus was given to the development of sewage disposal, since the purification of streams became essential in connection with the improvement of sanitation and the increasing appreciation of nature.

The increased interest in sewage disposal has resulted in an abundance of publications during the past few years. The hope for recoveries of value from sewage has led to the formation of committees of the technical directors of German cities, of the Society of German Engineers and of the Association of German Agricultural Districts. New sanitary districts and a national association for stream protection have also been formed.

The status of various sewage treatment processes is described below.

Racks and Screens.—Racks and screens are used to a limited extent. Coarse screens for interception of large floating and suspended matter are usually placed at the entrance to all sewage works. Mechanical cleaning is generally adopted. Screenings are either composted or burned.

Fine screens, and devices which remove a limited proportion of the suspended and floating solids from sewage, are used where such partial treatment suffices. Efficient grit chambers precede such screens. Only self-cleaning screens are used, such as the Riensch-Wurl disc and the Dorr and Geiger cylinders. Brushes clean the former and a current of water washes screenings from the latter to a settling or digestion tank.

Grease Traps.—Grease traps are now constructed to remove undesirable oil and grease from the sewage prior to biological treatment. The great increase in automobiles and industries has markedly augmented the discharge of oil and grease into the sewers, so that grease traps are now of more significance than formerly. Such traps consist of small chambers

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which provide a detention period of five to fifteen minutes. Air is introduced from the bottom to aid in the separation and flotation of oil particles, which may be partly attached to sludge solids. Proper baffling permits the formation of a greasy scum, which is drawn off the surface.

Grit Chambers.—Grit chambers precede settling tanks. They consist of elongated deep channels with flat bottoms. The velocity is reduced to one foot per second, to permit the deposition of sand, but not organic solids. Some grit chambers are aerated from below, in order to effect more perfect separation of sand. In such installations the velocity may be further reduced.

Recently grit chambers have been so constructed that the velocity remains constant with increasing volume and depth of flow.

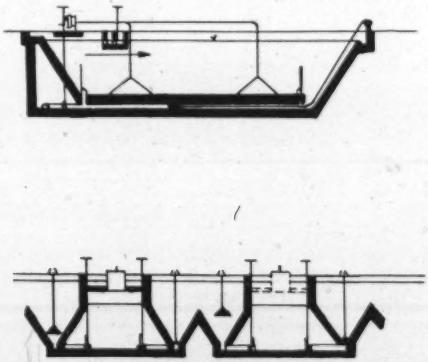

FIG. 1.—Longitudinal and Cross Sections of Neustädt Tank.

No grit chamber has been installed preceding the Imhoff tanks at Bochum, in the Emscher District. The grit settles with the sludge in the Imhoff tanks. There have as yet been no difficulties from deposits of sand in the tanks.

Removal of grit is usually accomplished by hand, although mechanical devices are now used in large plants. The grit is used for filling purposes.

Settling Tanks.—Settling tanks for separation of the settleable sewage solids are of two general types: In single-story tanks the solids settle in tanks with specially designed bottoms. The sludge is transferred from these tanks to other tanks, nearby, for digestion. In two-story tanks the solids settle through trapped slots to the lower compartment, where digestion takes place.

Sewage flows through the settling tank in a period of one or two hours, during which about ninety per cent of the settleable solids are removed.

(1) *Single-story Tanks.*—Single-story tanks are constructed so that the settled sludge is collected in troughs or hoppers, or is removed from a flat bottom by means of rakes. Sludge is collected in troughs in the Neustädt tank (Figure 1). When it is desired to remove the sludge, the trough is closed by means of a cover which separates it from the settling compartment, and the sludge is forced out by a piston. The fresh sludge is digested in an adjoining tank. In the Kremer tank the sludge settles into hoppers, from which it is pumped from time to time to the digestion tank.

Settling tanks with flat bottoms are circular, square or rectangular in plan. In the circular and square types the sludge is brought to the center

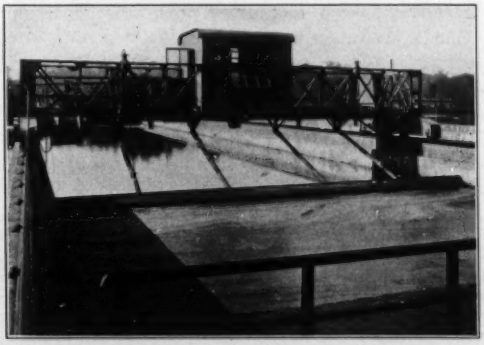

FIG. 2.—Mechanical Squeegee at Leipzig Skimming Surface of Settling Tank.

by rakes and collected in a sump, from which it is pumped to the digestion tank. Scum is likewise removed by a surface scraper. Such tanks, of the Dorr type, have been installed in the Ruhr District. In the Emscher District a new type of tank is installed at Essen-Nord, in which the rakes are attached to a float. These floats are revolved by a motor around a central vertical axis.

Long rectangular tanks are cleaned either by scrapers attached to endless chains, or by a single large pusher. The former type is installed in the settling tank at Werden, in the Ruhr District. The scraper at the Leipzig plant consists of a deep squeegee attached to a movable frame, which travels on rails at the sides of the tank above the water surface (Figure 2). The

squeegee, which spans the entire width of the tank, is lifted to the water surface at the outlet and moved back to the inlet. The sludge is collected in a sump and pumped to the digestion tank. In these tanks the sewage flows in the direction of the long horizontal axis. In the Essen tank radial flow is used, from the center to the periphery.

Hopper-bottom tanks are usually used for settling activated sludge. The mixed sewage and sludge is introduced at the center and flows under a baffle to a peripheral weir (Figure 3). The activated sludge settles and acts as a suspended filter for the rising sludge, retaining the finer suspended solids. This type of settling tank is well adapted to the flocculent nature of activated sludge.

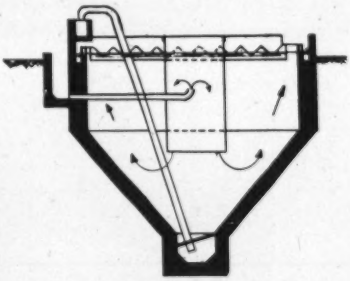

FIG. 3.—Cross Section of Type of Tank Usually Used in Germany for Settling Activated Sludge.

(2) *Two-story Tanks.*—Two-story or Emscher tanks have the advantage that the solids settle automatically into the digestion chamber, which is separated from the upper chamber by a trapped slot. Overloading the digestion tank with sewage is prevented by this construction. In Munich approximately one or two per cent of the sewage flow passes through the digestion compartment. It is believed that this stimulates digestion.

Two-story tanks have been used mainly in small plants, because of the simplicity of operation. An example of the low cost of operation of two-story tanks is furnished at Bochum, where only two men are needed for a flow of 22.6 cubic feet per second.

Digestion Tanks.—Freshly settled sewage solids are transformed into an easily dewatered and odorless sludge in a digestion tank. Single-story tanks require separate digestion tanks, in which fresh sludge must be mixed with well-ripened sludge and permitted to digest. In two-story tanks the digestion compartment is an integral or fixed part of the plant. The solids are introduced continuously in small particles into the digestion chamber, where they mix with the ripe sludge. Artificial mixing is not needed.

The advantage of shallow one-story tanks lies in their lower construction cost. Two-story installations require great depths, from 26 to 33 feet, and expensive construction. The disadvantages of single-story tanks are the more difficult operation and the complicated mechanical equipment for removal of sludge. The operation of two-story tanks is usually automatic.

The attendant needs only to keep clean the surface of the settling chamber and from time to time to withdraw digested sludge. The necessary mixing of fresh and ripe sludge is accomplished automatically. The conditions for single-story tanks are quite different. The attendant must draw sludge from the settling tank at least once daily, and must mix it with ripe sludge in the digester. Careful operation is essential for the success of such installations.

The simplicity of operation of two-story tanks is the reason for the widespread use of such tanks in small cities. In large plants, with intelligent operating control but unfavorable foundation conditions, single-story tanks

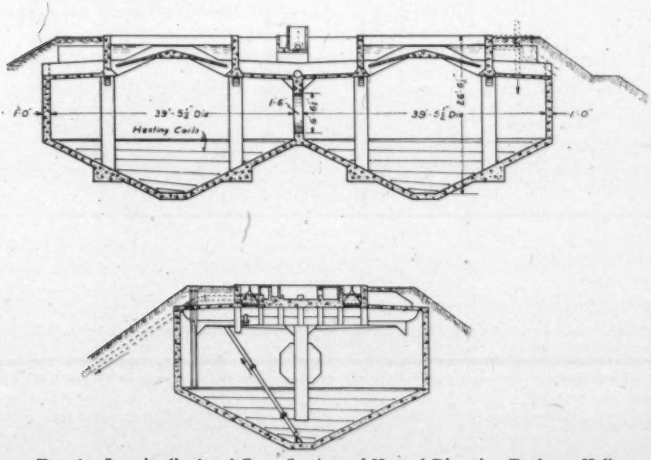

FIG. 4.—Longitudinal and Cross Sections of Heated Digestion Tanks at Halle.

are to be preferred. Usually specific conditions determine whether single or two-story tanks are best.

Recently there has been a combination of both types of tanks. The lower compartment of the Emscher tank serves for preliminary digestion, and a separate tank for final digestion.

The technique of sludge digestion has progressed rapidly. Investigations have shown the importance of the temperature of the sludge and its hydrogen-ion concentration. Sierp has shown that the optimum temperature is from 25° to 28° C. Since sewage, and therefore sludge, in German usually has a temperature of 10° to 15° C., the digestion tank must be heated to accelerate digestion. Heating of two-story tanks is impractic-

able, due to the excessive loss of heat. Separate tanks are provided with various types of heating equipment. Three types are in common use. In the Ruhr District the digestion tank is heated by introduction of hot water at 80° C., according to Imhoff's procedure. The hot water mixes with the sludge and gives up its surplus heat. Sludge liquor must be withdrawn in the same volume as the hot water. The digestion tank may thus be considered to be a flowing-through compartment. The discharge of ripe sludge must not be too complete or the desirable type of methane fermentation may be lost. For this reason this type of heating is limited to conditions where only a small quantity of water is needed. Another procedure is used by Prüss in the Emscher District. Fresh sludge is heated

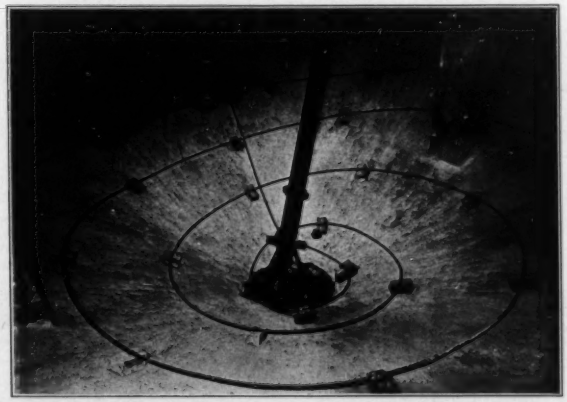

FIG. 5.—Copper Coils for Hot Water Used for Heating Sludge at Halle.

to 30° C. in an exterior tank before it is introduced into the digestion tank. The heated sludge is mixed with the larger volume of sludge in the tank by means of an interior screw pump on a vertical shaft. A third method of heating comprises the use of heating coils within the tank. This method is used at Halle (Fig. 4). Copper coils are placed in a spiral on the bottom of the tank (Fig. 5). Water is heated in a gas-fired boiler near the tank and circulated through the coils by a pump. In six months operation no difficulty has been encountered at Halle due to incrustation or other detrimental action.

The second requirement for satisfactory digestion is the control of the hydrogen-ion concentration between 7.0 and 7.6. Intimate mixture of

fresh and ripe sludge generally insures the proper methane-producing type of digestion.

Stirring of sludge may constitute a third requirement for acceleration of digestion. Mechanical stirring apparatus or pumps, of which the screw pump of Prüss has given good results, are used.

The use of sludge gas has had considerable development in Germany. It is collected from large digestion tanks and used for various purposes. It contains from 70 to 80 per cent methane, 25 to 30 per cent carbon dioxide and 0 to 8 per cent nitrogen. The heating values lies between 700 and 800 B. t. u. per cubic foot. Because of its high heating value the gas can be used for power, heat and light. Power required at the treatment plant may be produced by gas motors, thus considerably reducing the cost of electricity. The gas is usually mixed with coal gas of the city supply, which it fortifies. Piping for even 10 km. (6.2 miles) is warranted if the volume of gas is at least 1,000,000 cubic meters (35,000,000 cubic feet) per year. Usually from 3 to 5 cubic meters (105 to 175 cubic feet) of gas are recovered per capita per year. If activated sludge is also added, the volume is considerably larger. Accurate measurements of the additional volume are not available.

Digested sludge is either discharged into lagoons or dried on sand beds. In the lagoons it remains for fill. The cheapness of this procedure commends it, but the large areas required make it undesirable. The moisture drains from the sludge into the underlying sand. The moisture content decreases from 80 or 90 per cent down to 50 or 60 per cent. The dry sludge is removed by hand or mechanically and used for local fertilization. The humus content is of importance as well as the fertilizer constituents. Sludge might be called a biological fertilizer.

Biological Treatment.—Biological treatment is required if the flow of the receiving stream is deficient. Various processes are used in Germany.

Where sufficient land areas are available, sewage farms have been used, but have not been installed in recent years. The land can be utilized only part of the time, although the sewage is discharged continuously. The farms are now being supplanted by artificial treatment plants. The outstanding example is in Berlin, where formerly practically all sewage was treated on land, but more recently artificial treatment is contemplated.

Sewage is also sometimes sprinkled on fields and meadows. Such procedure has seldom been used heretofore, but more extensive use will develop where rainfall is deficient in areas near the treatment works. The plant and operation costs are generally quite high. A very large installation of this type has recently been installed at Halle. Part of the mechanically clarified sewage is pumped by sludge gas and distributed over the fields immediately adjacent to the treatment works.

Trickling Filters.—Trickling filters are still built. They are especially

suitable for small plants, since they require less attention than other artificial biological processes. Under special local conditions, such as at Stuttgart, where filter stone can be obtained very cheaply, large trickling filters may also be economical.

Contact Filters.—Contact filters are biological devices composed of surfaces submerged in the sewage and aerated from below. They are made of bundles of slag, brush or lath. Biological slimes grow on these surfaces. The air introduced from below forces the sewage up through these grids, and supplies with oxygen the growths responsible for the purification of the sewage. Lath grids appeared to be best for contact material. Air is introduced either through a fixed grid of perforated tubes or through a swinging perforated pipe. The detention period is usually not more than 30 to 60 minutes. An average of one volume of air is applied per volume of sewage.

The sewage must be clarified in a settling tank before entering the contact filter. Final settling is also necessary in order to remove the solids coagulated in the contact filter. The contact surfaces have been built in the central third of the settling compartment of Imhoff tanks, but usually without satisfactory results. It is preferable to install them in separate tanks. These devices remove from 30 to 40 per cent of the organic matter of the sewage, based on the biochemical oxygen demand. They are less sensitive to toxic industrial wastes in sewage than other biological devices.

Activated Sludge.—The activated sludge process, which was developed in England and the United States during the World War, did not become known in Germany until the close of the War. This process can purify sewage to complete clarification. The purification is accomplished by the so-called activated sludge, which is composed of flocculated sewage solids impregnated with microörganisms. The surfaces of the flocs are activated by the organisms and thus develop increased adsorptive properties. The flocs adsorb the colloidal and dissolved sewage solids. The organisms then feed on these solids. The process of purification depends upon intimate mixture of the sludge and sewage for the proper length of time, followed by separation of the sludge by sedimentation. The settled sludge is returned to be mixed again with sewage. The effluent, after separation of the sludge, is more or less purified. It is necessary to keep the sludge stirred in order to keep it activated, and so that it will not putrefy, likewise to supply oxygen for the microörganisms. Mechanical stirring devices, compressed air or a combination of the two are used for agitation and aeration. The brushes of Kessener and the paddle-wheels of Haworth have been investigated in Germany. Both devices beat the air into the water and at the same time circulate the sewage. These devices are not used widely and most installations are of the compressed-air type. The air is introduced either at one side, on the bottom, through filter

plates or through perforated tubes under the water surface. Circulation of the sewage during passage through longitudinal aeration tanks is accomplished by introduction of air at one side. In Kremer's process the mixture of sewage and air is lifted through a large tube by air applied through perforated pipes, and distributed over the water surface by flat baffles. Both schemes are under consideration. (*Editor's Note:* A letter from Dr. Heilmann states that the latter scheme has not been used to any extent in Germany.) A combination of compressed air and submerged paddle wheels has been used successfully at Essen-Rellinghausen.

The aeration period in activated-sludge treatment varies between four and fifteen hours, varying according to the concentration of the sewage. The quantity of air applied also varies widely, between one and eight volumes per volume of sewage (0.13 to 1.06 cubic feet per gallon). From 8 to 20 per cent of sludge is used, based on the volume of sewage. The excess activated sludge is disposed of most satisfactorily by digestion with settled sludge.

The final settling tanks provide a settling period of from one to two hours.

The reaeration of returned sludge was investigated at Halle, but results showed no improvement over direct return of settled sludge to the aeration tanks.

Recently two-stage aeration has been investigated. This scheme is expected to permit a reduction in the time of aeration. Conclusive data are not yet available.

Fish Ponds.—Fish ponds have only a limited use in sewage treatment. Usually either the necessary areas or the fresh water required for dilution of the sewage are lacking. Munich has recently constructed large fish ponds for biological purification of the entire sewage flow. The sewage is settled and then diluted with from three to five volumes of fresh water. The fish ponds are usually about three feet deep. The sewage of 2000 to 3000 people can be purified on one hektare (2.47 acres). Ducks are used for disposal of the surface growths of water plants. Data on the economics of the Munich scheme, as compared with other biological processes of sewage treatment, are not yet available, since fish from the ponds were not sold until the spring of 1930.

Chemical Processes.—Chemical processes are little used at the present time. Chlorination of sewage for removal of bacteria is in successful use at various places. As much as 20 p. p. m. must be used for assurance of removal of pathogenic organisms.

Industrial Wastes.—Industrial wastes may be treated most successfully in combination with human sewage. Special or private treatment plants for such wastes are justified only when they cannot be brought to the sewerage system, or if the cost of such connection is excessive.

The disposal of phenols from wastes of gas plants, coke plants and wood-

distillation plants is a serious problem. Industrial plants have been built in the Emscher District designed to extract the phenol from the wastes by means of benzol. The phenol is then removed from solution in benzol by means of a solution of caustic soda, which is ultimately disposed of as a solution of phenolates.

No improvement has been accomplished in the disposal of potash waste. These wastes, as well as those from ammonia-soda factories, salt works and all plants which discharge sodium chloride in waste waters, cannot be purified but must be diluted in the receiving stream under accurately prescribed conditions, and finally discharged to the sea or rendered innocuous by percolation.

Progress can be reported in the treatment of wastes from sugar factories. Various wastes are produced, which are treated best separately. The wash and transport water is settled for removal of dirt and beet tops and, after possible addition of coagulant and further settling, it can again be used. The Salzwedel fermentation process is used for treatment of the diffusion water. The waste is passed through fermentation ponds for removal of the sugar and afterward through more ponds in which anaerobic decomposition takes place.

I have mentioned only the most important industrial wastes, and those which have been found amenable to separate treatment. In general, satisfactory processes of sewage treatment are usually also applicable for industrial wastes.

The enormous volume of sewage from the closely settled cities of Germany has greatly polluted the various streams. In the Ruhr District the self-purification of the polluted streams is aided by the construction of reservoirs. The increased time of flow through these lakes results in an increased removal of polluting matter by biological agencies. The settled sludge must be dredged out from time to time. One of these lakes has been put into operation at Hengstey, on the Ruhr. This lake serves somewhat as a "chemical precipitation basin," since it lies below the confluence of the Lenne and the Ruhr. The acid water of the Lenne precipitates the suspended matter in the alkaline water of the Ruhr. The solids settle in Lake Hengstey. Some of the lower purely "biological" lakes are now under construction.

More sewage treatment districts have been established to provide more centralized and more economical disposal of sewage. The success of the Emscher and Ruhr Districts has led to the formation of the Lippe District to the north, and the Niers District on the left bank of the lower Rhine. Preliminary steps have been taken toward the formation of further sewage districts in other industrial regions.

Destructive Anaerobic Fermentation

BY F. R. O'SHAUGHNESSY, A.R.C.Sc., F.I.C. *

Anaerobic fermentation of putrescible organic matter is a natural phenomenon familiar to everyone. The farmer has made use of it from the beginning of his trade, and to many other industries it is quite indispensable. From time immemorial ancient practice established the fact that the proper use of this phenomenon would deal quite faithfully with the less volatile waste products of man's metabolism on a domestic scale; and within living memory the device known as the septic tank has served a similar purpose for the larger communities. Thus the thing we call sludge digestion now is only a new application of a very old practice, the principles involved being a little better understood at the present time. I prefer this approach to the consideration of this subject, as a proper appreciation of what has gone before is always helpful in adjusting one's sense of values and in maintaining that very desirable broad outlook.

That intensive fermentation of great masses of putrescible materials can be carried on in the open without the production of offensive volatile substances, is a fact so contrary to ancient tradition and experience, that it presents itself to the mind as something like a paradox; and it is perhaps not surprising that the factors which contribute to this rather astonishing result (only to be achieved by intelligent control) even now are not fully appreciated. To this question I shall return later.

The term destructive anaerobic fermentation is chosen above, as it distinguishes the main action from that in the aerobic attack on fermentable sewage solids which is usually accompanied by an integration of material form and potential energy, *e. g.*, activated sludge.

One of the purposes of this article is to endeavor to describe the happenings and the painful experience which at last led to the successful control at Birmingham of the reactions associated with the solids commonly carried by sewage, so that public amenities were no longer offended by the operations at the outfall works.

In passing it may be remarked that there is a little confusion as to the main purpose of sludge digestion at present. Dr. Mohlman has done well in pointing out in the April, 1930, issue of SEWAGE WORKS JOURNAL that "Notwithstanding the remarkable progress in research on separate sludge digestion it must be admitted that complete records of operation of large plants over a period of years are almost totally lacking, etc.;" and we can hope with him that "Within a few years these badly needed plant records may be available." These remarks serve to emphasize the fact that the

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main purpose of sludge digestion, as of all other methods, is disposal at reasonable cost; and the outstanding merit of sludge digestion is that it is now possible to effect disposal at inland towns without nuisance.

The records which are needed should include overall cost—the only basis on which the relative merits of differing procedure can be judged—and also the ultimate fate of the residual solids, a not unimportant point which is sometimes overlooked in the most surprising way.

At the point in the River Tame Valley where the main outfall of the sewers of the City of Birmingham are situated, there had been, prior to the introduction of separate digestion of sludge, for fifty years, the continually recurring intolerable odor of crude sludge. The scale of it may be judged from the fact that a wide area in that vicinity was kept in a semi-rural condition by its presence; and one does not know whether to sympathize more with the outraged feelings of the people who had the misfortune to reside in the ambit of the odor zone, or the harassed authorities and officials who tried so valiantly and for so long to achieve the impossible task of complying with legal injunction to eliminate the trouble. The tradition of that odor persisted long after it had disappeared; but now the whole district has been built up and it has been ascertained that residents in the nearest houses do not even know of the existence of the now innocuous sewage works.

From 1901 to 1911 part of the sludge was digested by the septic tank method, and part was dealt with by rapid trenching, thus mitigating somewhat the objectionable conditions. A very important fact was demonstrated by Mr. J. D. Watson during this time, namely, that the black slurry resulting from digestion of the sludge in septic tanks was inoffensive and could be dried quickly in bulk.

The introduction of septic tank treatment, however, transferred the difficulty from the sludge to the liquid; but instead of the acidic odors of the crude sludge the offenders were now volatile sulphides, which escaped from the liquid treated on the growing area of bacteria beds five miles away at Minworth. It may be remarked here, in parenthesis, that there is still confusion about the biochemistry of these odors, owing to lack of precise observation.

During these years, and because of this problem of public amenity which could not be avoided, the question as to whether restriction of the trouble might not be achieved by applying the septic tank method to a denser sludge was considered. Actually in 1906 an attempt was made to do this. Crude sludge (90% water) was pumped into a tank of 250,000 gallons capacity and kept under observation for several months. Needless to say, the result was disappointing.

The important and critical observations came two years later in 1908. Several large lagoons with earthen banks and about 10 ft. in depth had

been charged with sludge from septic tanks. The writer then noted three important facts:

(*a*) Very foul crude sludge was often pumped into these lagoons.

(*b*) The lagoons themselves although bubbling vigorously gave rise to no nuisance whatever.

(*c*) The sludge resulting from the action in these lagoons was a black slurry which had lost its original colloidal character.

Subsequently, much laboratory work was done and was followed by experiments in 1909 and 1910 in a working scale. The culmination came in the very hot summer of 1911 when the odor from the septic tank liquid sprayed on the bacteria bed at Minworth caused so widespread a nuisance that the digestion of sludge in the septic tank had to be abandoned. In addition, as it so happened, the land available for trenching sludge was found to be saturated with sludge.

It was under these circumstances that the "separate digestion of sludge process" (as it is now called) was inaugurated. The stark necessity for producing a method of treatment for the sludge of nearly one million people, which would cause no nuisance and deliver a handleable end product at tolerable cost was upon us—a stiff proposition, indeed, with experience then existing.

All the preliminary work alluded to above would have been useless without the large-scale plant record including costs, the results of which were given in my paper read at Birmingham University in December, 1913. It was essential to show also that the process was manageable on the largest scale and that the cost was reasonable as compared with other standard methods. Had that evidence not been forthcoming, or had it not been satisfactory, the whole proposition would have fallen to the ground and some other mode of dealing with the sludge would have taken the place of sludge digestion. Some of the points in this record which contributed to this successful result are of considerable interest when reviewed in the light of our present knowledge. They are dealt with in the appended discussion and are indicated as follows: For instance, the figures for the digestion tank capacity per head can be ascertained from the data given in the paper, and it appears to have been under 1.5 cubic feet. Such a low capacity is rather startling, but one of the most important reasons for this was the very dense crude sludge obtained by special means. The water content was often as low as 85% and averaged for the whole period about 86.6%, thus keeping the bulk low and giving maximum time in the available digestion tanks.

It may be pointed out that one of the objects of the investigation at that time was to ascertain the lowest limit of water content tenable in a sludge which was amenable to digestion; but it was demonstrated that it was not possible in practice to get a sludge so dense that it was not fermentable if

rightly handled. The other positive point made, as compared with modern practice, is the great importance of the water content as a factor in the economy of the process. Other important points which contributed to the success of this early effort were:

(*a*) The sludge flowed gently over a weir into the digestion tanks, thus ensuring thorough mixture of the acid crude sludge with a very large volume of the alkaline (buffered) sludge liquor, with a minimum of disturbance of the biological agents in the ripe sludge.

(*b*) The proportion of the batch of crude sludge to the contents of the digestion chamber was one to three or four. It has always been considered here that the law of mass action applies to these biochemical reactions; and this proportion, as against others, has since been checked, the results obtained (on gas yield rates) being in favor of this proportion.

(*c*) The sludge was heated by blowing in high pressure steam into the delivery pipe during the cooler months of the year so that warm sludge entered the digestion chamber. The view at that time was that if the right kind of biochemical change was initiated (the action not being reversible) the later action as the sludge slowly cooled in the tank would not be unfavorable.

(*d*) Another factor to which I attached great importance at that time, the value of which prolonged experience since has endorsed and amplified, was the division of the process into two stages.

(*e*) Still another factor which played a vital part in keeping the process going at critical times (periods of low temperature) in these early years, was the ease with which the sludge from the secondary sedimentation tank fermented and the speed with which it attained maximum activity as compared with the more heterogeneous sludge from the primary sedimentation tanks. The reason for this was to be found in its composition, for it consisted mostly of material of very fine texture and was in the main flocculated fecal matter, rich in fats and nitrogen and deficient in the acid-forming cellulosic bodies. Its quantity and the way in which it was used is recorded in the original paper; and it was most interesting to find Dr. Heukelekian three years ago confirming all these points.

(*f*) Mixing or seeding of the sludge played its part, the procedure varying according to the season (temperature).

Discussion

The procedure followed in Birmingham when adopting separate digestion of sludge in 1910–1911 was quite unique and differed profoundly from the procedure of that great pioneer Imhoff (whom I have always admired), as also from those who have developed so much interest in this question during the past five years or so. Previous experience in sludge digestion at Birmingham was chiefly with the septic tank, which involved a continuous

flow of liquid through the digestion chamber. Some of the earlier efforts followed this line, the amount of liquid being greatly restricted; but this was soon abandoned because of the very foul effluent liquor. The general procedure finally decided on was to put in a batch of sludge at one end of a horizontal tank and draw off intermittently (at intervals of two or three weeks) the digested sludge from the other end of the tank. Experience showed that this arrangement worked very well provided the average time of retention in the tank did not exceed about 2 to 3 months (some of those tanks are working to this day—18 years—and have not silted up). If the average time of retention exceeded 3 months trouble might be looked for sooner or later, owing to the slow accumulation of "worked out" sludge.

Two-Stage Digestion.—It was known that two to three months was not sufficient length of time to produce a well-drying sludge under the existing conditions. It was also known that if the sludge after 2 or 3 months storage in the primary tank was pumped over into a secondary tank several things, important in practice, happened:

(*a*) Some of the cruder sludge, which inevitably found its way by short circuiting to the end of the primary tank, was blended with the older sludge.

(*b*) The result of the blending was seen in the increased activity of the pumped sludge and the hastening of the ripening so that the sludge matured much earlier than if left at rest in the primary digestion tank.

(*c*) The material in the secondary digestion tank could be left to take care of itself, no heating being required as there was no fear of any nuisance developing on the one hand and the presence of "worked out" sludge caused no embarrassment on the other. (*Note.* It was found convenient to use the secondary tanks as storage tanks in order to cover the seasonal lag on the drying site. This storage capacity ought not to be included as digestion tank capacity.)

(*d*) A reserve of ripe sludge was always available for seeding the crude sludge in order to eliminate sterile pockets in the primary tanks.

(*e*) Thus the primary tank could be kept under very close control even in cold weather.

The work which Prof. Buswell of Illinois is doing on two-stage digestion is of the greatest interest. His results indicate further advantages by reason of better control if the operation is carried out in two stages.

Mixing.—There has been great controversy about this question, and it will be quite useful to review the known facts. At Birmingham mixing has been done as follows: A small quota of ripe sludge is delivered into the pump in order to eliminate sterile pockets in the crude material. The mass thus seeded is delivered quietly into a much greater mass of fermenting sludge in the digestion chamber. Thus the acids in the crude sludge are neutralized by the superior mass of alkaline sludge liquor, and the alkaline reaction favorable to the biological agents is maintained. This is achieved

with a minimum disturbance of the ripe sludge, in which the biological groups (symbiotic, etc.) were disposed.

The writer always considered it unwise to upset these biological groups and the very interesting behavior of the material pumped from the primary tank seemed to support this view. Although this pumped sludge had every appearance of renewed activity, and if left to itself would mature quite easily, it was always found that the amount of crude sludge which the pumped sludge would assimilate was very much less than a corresponding amount of unpumped sludge in the primary tank.

On the other hand, Dr. Prüss of Essen is very positive in his assertion that frequent mechanical stirring of the whole contents of the digestion chamber is most beneficial.

Other observers, Dr. Sierp of Essen, Dr. Rudolfs of New Jersey, recently Mr. Thompson of Leeds (England) and others, are not in agreement with Dr. Prüss. Prof. Buswell's practice of pumping round the alkaline sludge liquor (not the solids) on to the top of the scum on the contents of the digestion chamber is in accord, in principle, with the practice at Birmingham, although the procedure is different.

The writer has examined rather attentively the detailed arguments of Dr. Prüss (based on evidently careful observations made chiefly by Dr. Bach). A careful sifting of the evidence is worth while for some interesting points emerge.

If we consider the historical approach to the application of destructive anaerobic fermentation to the sludge problem at the two centres Birmingham and Essen, respectively, we see that the approach at Birmingham was by means of the septic tank, a horizontal-flow system, and the two-stage separate digestion initiated there is still a horizontal system. At Essen, on the other hand, the approach was by way of the two-story Imhoff tank, a vertical-flow system and Dr. Prüss's digestion tank is, from his own description, still a vertical system. With Dr. Prüss we all agree that two of the principal difficulties encountered in carrying through the anaerobic fermentation of the sludge to a successful issue are the tendency for local accumulation of toxic products and then the embarrassment due to "worked out" sludge on the other. There is no dispute there. The procedure decided on at Birmingham and later elsewhere, to overcome these and other difficulties was to divide the horizontal system into two stages, restricting the time capacity of the primary stage. Thus, many years experience has demonstrated that the gentle automatic movement set up by gas formation washes the sludge particles and prevents silting. In addition, it may be remarked that dense sludges of low water content may be dealt with by this plan.

Dr. Prüss states that because of the design of his tank he cannot with advantage carry sludges having a lower water content than 95 per cent owing

to close packing of new and old sludge in the lower portions of his tank. He has evidence that owing to this, and also the accumulation of toxins, bacterial life in the dense mass is seriously interfered with. Thus he is compelled to insert mechanical stirrers to bring up the sludge from the bottom to the top of the tank and so to allow the sludge to be washed in the aqueous zone, thus overcoming that defect in his tank. Dr. Prüss makes one claim to which he appears to attach great importance, but which is, in my opinion, probably a disadvantage. He states, on the authority of Dr. Bach, that fresh sludge coming into contact with old "worked out" sludge in the digestion chamber causes a new attack upon and a further destruction of the latter. Now I have pointed out what surely should be obvious to all, that one of the main purposes in applying sludge digestion is disposal without nuisance; and an excellent example (in which I still take a paternal interest) of where digestion is directed to this single end, exists at Bath (England). There, conditions are favorable and permit a short period of digestion without excessive exhaustion of the organic matter. As a result, the digested sludge from 80,000 people is in such favor with the local farmers that carters actually stand in queues to get it, the demand being greater than the supply. Thus complete disposal appears to be accomplished economically. As against this it does not seem likely that the extra quota of gas which Dr. Prüss claims to obtain by further exhaustion of the sludge, can compensate for the above facile disposal.

Reaction.—Long experience at Essen, Bath, Birmingham, and elsewhere has led to the conclusion that the optimum pH value in the digestion chamber is best maintained by proper ordering of the procedure so that the reserve alkalinity in the strongly buffered alkaline sludge liquor is drawn on in an appropriate manner. Prof. Buswell is apparently of the same opinion, and the results he has obtained, by pumping sludge liquor only, are very striking; while Dr. Heukelekian of New Jersey, who has investigated the matter very thoroughly, has demonstrated the superiority of the alkaline sludge liquor over lime. Recently, in conversation with the writer, Dr. Imhoff likened the use of lime in connection with sludge digestion to a man, who through carelessness, has given himself indigestion and then must take chemicals to give himself relief.

Odor.—The question of odor is so important that the need for control of it has been one of the principal driving forces in the development of sewage disposal and in particular sludge treatment. It is mentioned here because there are certain points of practical significance which need to be cleared up. The writer's experience is that the proportion of water in contact with putrefying sludge plays a considerable part in determining the character of the volatile materials. Crude sludge gives off acidic odors *but no sulphides*. In the old septic tank, where the volume of water in contact with the sludge was very high, the methane ferment was developed, but

practically invariably accompanied by sulphides; and it is noteworthy that analyses of gases from Imhoff tanks often show sulphides present, probably for the same reason. I am not aware that gas from the separate digestion of sludge has ever been found to contain sulphides; and experiments in the laboratory confirm this influence of water on the production of volatile sulphides. A most striking example is that of Bath. There, the sewers receive a very large volume of water from the hot springs and much of the material in solution in the spring water consists of sulphates. Before chlorination was started, these sulphates gave rise (by reduction in the pumping main carrying the sewage) to sulphides, the effect at the outfall of the main being painful. When separate digestion was installed these sulphates never gave rise to sulphides in the digestion tanks, the odor from which was the usual faint tar-like odor.

Information on this question of odor would be welcomed by the writer. Views have been put forward from time to time, not always in harmony with the facts, to account for the absence of offensive odor from a properly managed separate digestion plant. It is of course essential that all the conditions which contribute to the production or the disappearance of odor (with description of the odor if present) should be clearly stated.

Sludge Gas.—In recent years increasing attention has been given to the production and utilization of sludge gas from digestion tanks for light, heat and power. There was more than a fear that attention would be diverted from the main purpose of controlled sludge digestion, which is of course disposal, by this interesting by-product; and indeed it has actually been stated in responsible quarters that gas-production is a principal object. Quite recently, however, Mr. H. C. Whitehead, M. Inst. C. E., who has installed at Birmingham the largest plant in existence for the utilization of sludge gas has emphasized the fact that, useful as this gas undoubtedly is, the proper view is that it is still a by-product from the main operation of sludge disposal.

The excellent paper by Mr. W. H. Fulweiler in SEWAGE WORKS JOURNAL, July, 1930, served a like useful purpose in demonstrating very clearly and in great detail both the possibilities and the limitations of sludge gas.

Temperature

Most of the research work done in connection with sludge digestion may be said in effect to have been concerned with the influence of temperature on the speed of the processes. From the beginning at Birmingham it was known that a rise from 50° to 70° F. greatly expedited the action in the septic tank, and similarly by blowing high pressure steam from Lancashire boilers into the crude sludge delivered to the digestion tanks in the cooler weather, from 1912 onward the action was favorably controlled.

In 1924 Dr. E. A. Cooper and Mr. R. B. Tunstall at Birmingham Uni-

versity investigated the effect of temperature from 0° to 18° C. on the rate of evolution of gas and also elicited much other useful information. Among other investigators, notably Dr. Sierp of Essen produced his temperature curve showing optimum temperature (again on the basis of rate of gas evolution). Similarly Dr. Rudolfs and Dr. Heukelekian have investigated effects of temperature; and lately they and others have done work on still higher temperatures, the practical significance of which is problematical.

It appears that the problem of securing the advantages on a large scale, which would undoubtedly follow if temperature could be easily and satisfactorily adjusted to the known appropriate level, is surrounded by greater difficulties than are at first apparent. Possibly this is one of the causes which holds back the production of satisfactory plant records. Not until these are forthcoming shall we be able to judge the net benefits, if any, of the latest results of laboratory and small-scale investigations.

Summary

The main purpose of modern sludge digestion processes is disposal of the sludge without nuisance and at reasonable cost.

The Imhoff tank (vertical method) and the separate digestion of sludge in two stages (horizontal method) are not embarrassed by accumulation of toxins or "worked out" sludge. The latter method is more elastic and gives better control of odor and other difficulties Mechanical mixing is unnecessary in either process.

From Dr. Max Prüss' description, the design of his tank for separate digestion of sludge is not well suited for sludges having a lower water content than 95 per cent, owing to interference with bacterial action by reason of the packing of the sludge in the lower portions of his tank. He is thus compelled to use vertical screws or worm-like mechanical stirrers to overcome this defect in his tank. His claim, from his own experience with his own design of tank, that vertical mechanical stirring is essential to the process, is not accepted by other experienced observers. With other procedure they find mechanical disturbance either injurious or without beneficial effect. Undue exhaustion of the sludge, which is claimed by Dr. Prüss as an advantage, is more than doubtful and very likely a disadvantage.

Sludge gas is very useful but subsidiary to the main issue of sludge disposal.

The biochemistry of odor production and control needs further investigation.

Water content, temperature and reaction (pH value) are among the principal factors influencing the environment in which the dynamic elements, the biological agents or bacteria, work.

Destructive anaerobic fermentation is chosen for a title to distinguish

the action from aerobic attack on sewage solids. Aerobic biological attack is generally accompanied by the integration of material form and potential energy, *e. g.*, activated sludge. Anaerobic action, however, is destructive of organic structure and is accompanied by release of energy, as Dr. Sierp has very picturesquely shown.

Two-Stage Contact Aerators for Sewage Containing Phenol in Hattingen. F. FRIES. *Tech. Gemeindebl.*, 1930, **33**, 206 and 221.—The new sewage works of Hattingen, which were brought into operation in 1929, are planned to deal with domestic sewage. the waste water of small industries and the waste water from a large iron works, including a coke and by-product factory. This phenolic effluent amounts to about 20 per cent of the dry weather flow. The sewage flows through screens and a flat sand-trap specially designed to deal with great variations in flow. A storm-water overflow to a storm-water settling tank is situated between the sand-trap and the oil-trap. The oil-trap consists of 3 chambers of which the central chamber is aerated; the rising oil collects on the surface of the side chambers and is disposed of by burying in the ground. The sewage is then pumped to Emscher tanks from which the sludge flows to drying beds. The digestion chambers are heated by the water previously used in coolers of the power plant where the sludge gas is utilized.

The contact aerator plant is in two stages. The first contains wooden laths fixed in wooden frames attached to a central axis and movable from above. The second tank contains cork cubes packed in a wooden framework. Aeration is through pendulum pipes moving between the frames and the tank bottom. Each stage is followed by a settling tank and the retained sludge is conveyed by the sewage pumps to the Emscher tanks. The effluent from the aerators is practically free from phenols, odorless, clear and transparent. Measured by biochemical oxygen demand the purification is about 69 per cent. Efficiency of the contact aerators depends largely on freedom from sludging and fungus growths in the aerators.

The gas from the Emscher tanks is collected and used to produce most of the power required to pump the sewage, supply compressed air and drive the pendulum aerators.—Abs. No. **68**, *British Summary of Current Literature, Water Pollution Research*, Vol. IV, 1 (January, 1931).

Operation of Sewer Rental Laws*

BY FRANK WOODBURY JONES**

During the past ten years the operation of sewage treatment plants has been given more real consideration on the part of municipal officials than ever before. Persistent education, both by precept and by the example of disreputable, non-productive sewage works, is gradually dispelling the once almost general notion that sewage plants operate automatically, and is arousing an intense desire on the part of the lay official to learn how the sanitary works serving his community can best furnish the benefits for which they were designed.

The operation of sewage plants requires funds. It is not always easy, however, to find the money to increase an unpopular item in a budget already strained beyond capacity. Consequently, in many cases where officials have been continually urged by constituted health authorities to operate their sewage plants efficiently, the reaction has been to reply that the plants would be operated if means were supplied for securing the necessary funds.

Sewerage as a Utility.—Sewerage works have long since passed beyond the convenience stage. The system is not merely a vehicle for carrying off that for which there is no further use. Sewerage unquestionably is a public utility. Public demand for a pure and wholesome water supply makes necessary expenditures adequate to meet the requirements, both for supply and maintenance. If the water is received sufficient in quantity and satisfactory in quality, there is little or no complaint, and after use it is turned to waste with little thought or concern as to its destination. The municipal authorities, however, have two problems: One, to provide a suitable water supply, and the other to dispose of it in a sanitary manner after it has been changed from pure water into sewage.

It is far easier to provide funds where tangible and direct benefits are derived, than for uses where the benefits are not so apparent. Consequently, a water works system is usually self-supporting, whereas, that poor relation of the municipality, the sewage treatment works, usually goes begging and neglected. The question naturally arises as to whether sewage disposal is so closely related to water supply as to become a part of it. Is it not just as necessary to provide funds for the removal of used water from our premises as it is to bring pure water into them? The logic of the conclusion that the sewer system is, in reality, a public utility, furnishes the basis for our existing laws permitting charges or rentals for its use.

* *Presented at Third Annual Meeting of the Central States Sewage Works Association, Springfield, Ill., June 9, 1930.*

** *Sanitary Chemist, George B. Gascoigne, Consulting Sanitary Engineer, Cleveland, Ohio.*

Development in Usage of Sewer Rentals.—The assessing of charges for the use of sewer systems and sewage treatment plants is not new. The City of Brockton, Massachusetts, has been making and collecting such charges successfully since 1894. While not directly comparable, the making of charges to connections outside a municipality, for service inside that municipality, is of long standing and quite general practice. As will appear subsequently, the State of Pennsylvania passed a sewer rental act relative to boroughs some thirteen years ago. It appears, however, that the enactment of the sewer rental law in Ohio in 1923 and its adoption shortly afterward by several municipalities, were the real starting points of the widespread interest developed during the past five years in this method of financing sewage treatment.

Present Status of Sewer Rental Laws.—It is my understanding that sewer rentals are now permissible by law in the States of Massachusetts, Pennsylvania, Ohio, Michigan, Wisconsin and North Carolina, and possibly some others.

The several enabling acts have been quoted widely in recent technical literature and need not be repeated here. You are referred to a comprehensive article by Mr. Frank A. Marston, of Metcalf and Eddy, published in the 1929 *Proceedings of the Society for Municipal Improvements*, under the title: "Charges for Sewerage Service," and to another by Mr. N. T. Veatch, Jr., of Black and Veatch, published in *Water Works and Sewerage* for November, 1929, under the title: "Financing the Operation of Sewage Disposal Plants." The Reports of the First and Second Ohio Conferences on Sewage Treatment give comprehensive data relative to the law in Ohio.

Use of the Sewer Rental Law.—In order for the provisions of the state sewer rental laws to become effective, ordinances to establish the necessary schedule of rates must be passed by the municipality seeking the benefits. In spite of the widespread interest of recent years the present usage is still rather restricted.

In Massachusetts, besides the City of Brockton, at least two other municipalities are collecting charges for sewerage service. No data relative to North Carolina are available.

Mr. Warrick, State Sanitary Engineer of Wisconsin, writes that this law has been in effect about one year in Wisconsin, but to date there are no municipalities availing themselves of its provisions.

Mr. Holmquist, Director, Division of Sanitation, states that the sewer rental law was enacted in New York State in 1929. No municipality has as yet adopted a scale of rents.

The Michigan Home Rule Act as amended in 1927, and again amended by Act 126 of the Public Acts of 1929, provides for sewage disposal as a utility within or without the corporate limits of a city. Mr. Rich, Director

of the Bureau of Engineering, states that the Village of Clio which is now building a sewer system, a sewage disposal plant and a water supply is the first municipality in Michigan to adopt this plan. It is not yet in operation.

Mr. H. E. Moses, Assistant Chief Engineer of the State Department of Health, sums up the situation in Pennsylvania as follows:

In Pennsylvania an Act relative to boroughs was passed in 1917 specifying that the borough may provide by ordinance for the collection of an annual rental or charge for the use of the sewer system from the owners of the property served by it; such annual rental shall not exceed the amount expended in the maintenance, repair, alteration, inspection, depreciation or other expense in relation thereto.

In 1925 the Pennsylvania Legislature passed an Act relative to cities of the third class, stating that "cities may provide by ordinance for the collection of an annual rental or charge for the use of the sewer system or sewage disposal plants from the owners of property served by it, the amount collected not to exceed the amount expended in operation, maintenance, repair, alteration, inspection, depreciation or other expenses in relation to such sewer, sewer system or sewage disposal plant."

In the Township Law of the State it is provided that townships may establish and construct a system of sewers, etc. All persons so connecting, etc. The Commissioners may permit and where necessary for public health require adjoining and adjacent property owners to connect with and use the same. All persons so connecting shall pay in addition to the cost of making such connection a monthly or annual rate prescribed by ordinance. Such monthly or annual rate shall constitute a lien, until paid, against the property so connected with such system and the amount thereof may be recovered by due process of law.

I do not have a complete list of all municipalities in the State where a sewer rental is charged, but we know that in the Philadelphia Section sewer rentals are charged in the Townships of Lower Merion, Haverford, Radnor, Cheltenham and the borough of Jenkintown. Possibly also in the borough of Doylestown. The borough of State College at one time charged a sewer rental and I believe this method is still in existence.

In the borough of Troy, Bradford County, in the northern part of the State, a community of about 1400, there was urgent need for the installation of a sewer system with a lack of municipal funds to install the same. Consequently, private capital provided the funds with a trustee operating on behalf of the investors and the system was leased to the borough at a semi-annual rental equivalent to 5% per annum on the money invested, the borough to have the option of purchasing the proposed sewer system and sewage treatment works.

I find from a copy of the ordinance "that the borough of Troy will operate and maintain said proposed sewer & sewage disposal plant during the term of said contract, granting to the citizens and property owners of said borough the right to use said sewer for reasonable rentals to be paid quarterly in advance* * *."

Also "that the rentals received by the borough of Troy for the use of said sewer shall be used only for paying the rent reserved in said contract, maintaining and repairing said sewer and sewage disposal plant, the payment of other expenses connected therewith and in purchasing the interests of investors therein."

In Ohio, at the present time there are at least ten villages and cities where sewer rental charges are in actual operation. One city council passed an ordinance, but it was voided by referendum vote at a regular

election. This city, however, plans to try again. Another city had passed an ordinance establishing sewer rentals, but annexation changed the plans. Besides those communities where the sewer rental laws are in actual use, there are at least a dozen more places which have given the matter serious consideration, even to the extent of having tentative schedules set up and ordinances drafted. Undoubtedly many of these will adopt the plan.

Basis of Rentals.—There are two general methods used for establishing schedules of rentals: One based on the amount of water consumed, and the other based on some flat rate, depending upon the type and number of connections. Factories and colleges are sometimes charged on a per capita basis. There are various modifications of both these methods, all of which are described in detail in the literature already referred to. Where there is a sliding scale there is also a minimum charge. The most popular charge is $4.00 or $5.00 per connection per year.

In general, it would seem that where a municipality owns and operates a metered water supply, sewer rentals based on the water consumption records appear most reasonable. On the other hand, where a community is served by a private water company, or where there is no metering, some form of the flat rate is more applicable.

The setting up of a suitable schedule of charges should be approached most carefully. The amount of revenue required must first be determined. The number of sewer connections must be known. If the rates are to be based on water consumption, using a sliding scale above a minimum, a careful analyses must be made of the water consumption, preferably over not less than a three-year period. Large consumers must be listed and in some instances deductions made for water not returned to the sewers, such as railroad supplies. When all of these facts are in hand, basic rates may be set up which will produce an aggregate revenue adequate for the requirements.

Where a flat rate is adopted analysis of the types of connections must be made with equal thoroughness. The end sought in all cases is to have the charges adequate and at the same time equitable, so that no undue burden will be placed on either the large or small user.

Method of Collection.—Where the sewer rentals are based on water consumption, bills for both water and sewer service can be sent on one card. The amounts due each are calculated from the same meter readings. This not only minimizes labor and supplies, but the fact that both bills are on the same form adds to the effectiveness and simplicity of collection.

Where the flat rate is used a separate billing and collection agency must be maintained.

Bills are usually made out to be paid quarterly in advance. One or two have semi-annual charges. Some provide for discount if payment

is made, others for a penalty if payment is not made, before a stipulated date, usually 10 or 15 days from date of bill. The penalty seems to be preferable to the discount.

How It Works.—Personal observations and replies to inquiries sent to various cities and villages in the State of Ohio, where sewer rentals are known to be collected, warrant the conclusion that wherever the plan has been adopted it has been highly successful. Available data show that the rentals are paid promptly and that there is little loss. Sewer rentals constitute a lien on the property and may be collected as other delinquent taxes. This is expensive and time consuming. Moreover, it is not so easy to plug a sewer as it is to shut off a water connection. Consequently, the fact that there is so little loss speaks well for the practicability of this plan.

The greatest source of complaint arises from the feeling that it is a class tax. In this connection it may be observed that where the sewer rental is now operating most successfully the greatest lessons have been obtained in the past relative to what happens when sewage plants are improperly operated and neglected. In two cases with which we are most familiar, municipalities have placed in operation recently new sewage treatment works of modern type, with sufficient funds for operating them raised by means of sewer rentals. Both of these municipalities had sewage plants previously, and in each case they were allowed to fall into disrepute largely by reason of neglect. There is no question but that one of them at least would still be in service if the same care and attention had been given it that is now given to the new plant.

All old plants which are now operated by means of sewer rentals are receiving better care and attention than ever before and are producing better effluents. New plants are enabled to start off properly and can be maintained in such a manner that they are a credit rather than a disgrace to the community.

The funds now derived where sewer rentals are in force usually supply all of the money necessary for operating the disposal plant. In some cases it is sufficient also to take care of the maintenance and upkeep of the sewer system, while in one or two other instances there is a surplus which can be utilized for the payment of interest and capital charges.

Benefits of Sewer Rental.—The fact that a municipality may establish a schedule of sewer rental charges is productive of benefits both direct and indirect. The direct benefits accrue when ample funds are made available for the proper upkeep and maintenance of a sewage treatment works. This not only provides for the plant turning out a good effluent, but makes possible also longer life for the various structures. Where funds cannot be provided otherwise there is now no logical excuse for neglecting this important phase of municipal housekeeping. On the other hand, muni-

cipalities which heretofore claimed they could not secure funds from their general tax revenue to operate the sewage plant now find that this is possible, since the argument that there is no way of providing funds no longer holds. In one instance a special tax levy was voted by the people for a five-year period just to provide funds for operating the sewage treatment works.

In conclusion, it may be stated that the adoption of sewer rental charges is not yet of very wide application. However, interest in this scheme is growing each day and, in view of the improvement possible in the operation of sewage plants where this method is employed, the plan will undoubtedly gain favor. Proper education relative to the needs for sewage works maintenance and methods for providing adequate funds must be continued. Five years' experience with the sewer rental law has demonstrated its practicability. It should be emphasized, however, that this law was intended primarily to provide funds for the operation of sewage treatment plants. Attempts to apply its provisions to cover capital charges by special financing may cause a reaction, and defeat the whole purpose of a workable and effective means of raising the plane of a municipal function too long neglected.

Sewer Rentals*

BY HAROLD S. CROCKER**

The subject of sewer rentals is necessarily a sub-topic under the general consideration of financing a system of sewerage and sewage disposal.

A sewer department may well be thought of as a public utility and may be operated as nearly as possible like one. It may be financed by assessing betterments, by levies from general taxation, by rental for use of the system, or by a combination of any two of these methods, or by combining all three. The combination of all three is absolutely essential for a thoroughly equitable financing plan. A division of the capital and operating costs of a system must be made which will separate the benefits derived by the public from those acquired by the individual. Otherwise, there would be no excuse for this presentation.

The cost of main sewers and disposal, including pumping and treatment plant, are items of cost that may well be paid from general taxation. This is particularly true in the case of a sewerage system for a city, town or sewerage district, because there is a benefit derived by all where a system is constructed. It is well to remember that personal property does not receive a benefit as does real estate, and general taxation does not recognize a difference. There might be a question as to the justice of this method in the case of county systems, where large areas are agricultural and will be for many years, and therefore would acquire little benefit. As such systems are unknown in New England, so far as my knowledge goes, it will be unnecessary to treat such a case here.

The public benefit is, of course, greater with combined sewers than with separate. By using the method of assessment of betterments against properties lying on the line of the sewers as an addition to the financing by general taxation, inequalities may the more readily be overcome, whether the system is for a city or town, or for a county or whether the sewers be combined or separate.

Benefits derived from a system of sewerage may be classed thus: (*a*) greatest to the user; (*b*) next to the owner of land; (*c*) least to the community at large. Payments should be made accordingly.

The General Laws of Massachusetts recognize that benefits derived are not in proportion to valuation. Section 23 of Chap. 83 provides that any city or town shall pay "not less than one-quarter nor more than two-thirds, of the cost of laying out, constructing, maintaining and repairing the common sewers" from the general tax. In other words, the remainder must be financed by assessment on the abutter or by rental against the user.

* *Presented at Second Annual Meeting, New England Sewage Works Association, Boston, Mass., April 15, 1930.*

** *City Engineer, Brockton, Mass.*

The Rhode Island General Laws contain no provision which authorizes towns or cities to make rental charges, so I am informed. The same thing may be said of the General Laws of the State of Connecticut, although it is thought that a bill will be presented to the 1931 Legislature which, if made a law, would legalize sewer rental charges.

The Enabling Act in Massachusetts is contained in Chap. 83 of the General Laws. Section 16 of that chapter reads as follows: "The aldermen of any city, except Boston, or the sewer commissioners, selectmen or road commissioners of a town, may from time to time establish just and equitable annual charges for the use of common sewers, which shall be paid by every person who enters his particular sewer therein. The money so received may be applied to the payment of the cost of maintenance and repairs of such sewers, or of any debt contracted for sewer purposes."

This section of the General Laws, or rather the similar section in use before the revision of 1921, was declared to be constitutional thirty years ago by the full bench of the Supreme Court of Massachusetts, in the petition of William H. Carson *vs.* the Sewage Commissioners of Brockton; 175 Mass. 242. This action was affirmed by the Supreme Court of the United States in 1901; 182 U. S. 398.

Mr. Carson endeavored to show that the state law and the city ordinance were both unconstitutional. In denying the petition the Massachusetts Court ruled, in part—

> .....We are of opinion that the petitioner received a special benefit for which he might be charged,.....No one denies that it was a special benefit to the petitioner to have a sewer built in front of his land. That benefit was the probability that the sewer would be available for use in the future. But the City, by building it and receiving a part of the cost from the petitioner, did not impliedly bind itself or the general taxes that the sewer should be maintained forever and that the petitioner should be at liberty to use it free of further expense. If building the sewer was a special benefit, keeping the sewer in condition for use by such further expenditure as was necessary was a further special benefit to such as used it. The charge allowed by the Act is a charge for using the sewer, a benefit distinct from that originally conferred by building it. By the Statute the charge must be a 'just and equitable charge.'....Here the words are applied solely to those who actually use the sewer, therefore, the benefit to the parties assessed is established.
>
> The assessment in order to be equitable must be proportional to the benefit and not in excess of it. The words in this connection sufficiently express an intent to confine the charge within constitutional limits. They are so construed by the Ordinance; for by the Ordinance the charge is in proportion to the extent of the use, which is a reasonable way of estimating the extent of the benefit received.....
>
> If he is dissatisfied with the rate he is not obliged to use the sewer. But if he were compelled by law to use it and to pay as now for the use (st. 1890, c. 132), and recognizing as we must the possibility that, in spite of the meaning which we attribute to the Statute, the rate fixed by the Ordinance might be in excess of the benefit received, still in our opinion the Act and Ordinance would be valid, notwithstanding that mere possibility in the absence of any allegation that the rate fixed did exceed, in fact, the benefit

received. In cases of this sort the petitioner has no right to appeal to a jury. Howe *vs.* Cambridge, 114 Mass. 388. The final decision must be somewhere, and may as well be left to the city council as to anyone....."

The Brockton Ordinance at that time provided for payments for rental based upon the water department's meter readings, of 30 cents per 1000 gallons of water consumed. If the property was not metered a flat rate of $8.00 per year was charged.

The financing of a sewerage system by rentals alone, as previously stated, would not be equitable, because the entire district receives some benefit from a sewer system. It is bound to be a step toward better health for the community. All the people should, therefore, pay something for this benefit by having part of the cost paid from the General Tax. The owner of land receives a particular benefit if the sewer is laid by his property. A future building thereon may be connected with the sewer or the land may be drained if necessary, if the sewer is for storm water. Unquestionably, it has been proved that the potential value of a sewer increases the property values. An assessment for this special betterment should be levied.

If the entire financial structure were to be based upon revenue from rentals, it would place an obligation on the part of all owners to connect their structures with the sewer. Otherwise, costs to those who did avail themselves of the privilege would be so high that courts probably would rule that instead of fixing equitable rates, the department was actually charging so much that it amounted to the taking or destruction of the property. In this event, a new financial policy would of course be required.

If all property owners should be compelled to connect with a system, it would be an injustice to many, especially the small property holders, as well as a heavy burden upon some who could ill afford the large outlay incident to the cost of a connection and the subsequent expense of rentals.

Looking back over Massachusetts laws we find that the necessity of drainage of individual estates was recognized in Chapter 14 of the Acts and Resolves of the year 1797. This early act recognized the right of the individual to build drains in such a way and manner as the selectmen might permit or direct, also the right of one or more persons to build a drain so that it would benefit not only him or them, but others. These builders would be the owners of the drain and were given authority to collect from persons connecting with the drain, or others whose cellars or lands were benefited, a proportionate part of the cost of repairing the same. The selectmen were empowered to determine this apportionment and to rebuild or repair these common drains which were private drains and at the same time public drains, and to assess the cost upon all persons benefited.

Thus the legislature of this commonwealth recognized the necessity of rentals one hundred and thirty-three years ago.

When accessors value property for the general tax each year, they are able to recognize the different uses that properties are put to and accordingly change valuations from year to year as may be necessary to equalize taxation, using their best judgment. If a sewerage system were paid for entirely from the general tax, including also its maintenance, special benefit to individuals or corporations would not be recognized as it is by the assessors from year to year. The same would be true in the case where betterment assessments would be levied upon properties past which a sewer might be constructed, in accordance with the type of structure, if any, built upon the lots. Take, for instance, three lots of equal value, one unimproved, one with a single family dwelling, and one with a manufacturing concern that discharges large quantities of water into the sewer. Assessments levied now in proportion to use, would prove a hardship on the third lot mentioned, if that structure were removed by fire or other cause shortly after the assessment was levied.

A system of rental based upon use will defeat any such inequalities as might well happen as cited above.

The greatest benefit derived from a sewerage system goes to properties along the sewer lines. By far the greatest amount of expense for operation and maintenance results from the connections to the street sewers. This is particularly true in the case of cities that have pumping stations and treatment works. The entire cost of operation and maintenance should be paid by those to whom the service is rendered, by the collection of rentals.

It is the populous district that demands the water supply, and it is the taker of this water who demands the sewer. The water-taker's need of a sewer is directly proportionate to the quantity of water which will enter the same; therefore, it seems just that, as the water-taker pays for the water he uses, he should pay for the facilities for removing this water.

There is an exception to this, however, in the case of manufacturing plants that consume a quantity of water in their processes, also the individual who uses water for lawns and gardens. In these cases and other similar ones, abatements must be made for water not entering the sewer.

Rental based on the water consumed would be a simple method, easily comprehended, and ideal to this extent at least—that the variable amount which the consumer would have to pay would rest in his hands and not in the hands of the city; but to be perfectly fair the method would require that all buildings connected with the water service be metered and separate meters applied to the water not entering the sewer. There can be no objection to the metering method, because it is practically universal for cities and towns to approach one hundred per cent metering of their water supplies.

In the case where metering of water services is limited or entirely negligible, rates may be based upon the number of plumbing fixtures in use; or upon a flat rate per dwelling; with, of course, an equitable sliding scale for tenements, lodging houses, stores and manufacturing establishments, or upon a system that would combine both of the above.

A rental law is more easily enacted and necessarily more equitable if adopted at the time a sewerage system is constructed. The same might be said if the rental law is applied at the time a new treatment works is put into operation. To adopt a scheme of rentals after a sewerage system is in use is a difficult undertaking, but it is by no means impossible. An educational program, to show the citizens the fairness and equality of the method of financing by use of rentals for the proper operation and maintenance of a sewerage system would, I believe, result in its adoption. An improperly operated system of sewers and sewage disposal, due only to lack of finances, leads to pollution of streams, spread of disease, law suits, and—in the end—brings upon a community an unhealthful condition and a larger expense than would result if money were spent judiciously in the first place. It is often easier to get the necessary money through rentals than by appropriations through a budget.

Massachusetts considers the rental so important that, if a bill is not paid when rendered by the sewer department, it may be committed by the assessors for collection and placed upon the tax bill. It then becomes a lien upon the property and is collectable in the same manner as taxes.

The proportion of money to be collected from general taxation, assessments, and rentals, as well as the amount per unit of each of the latter two, cannot well be stated to be generally adaptable everywhere, because each district, city or town has a problem that is peculiar unto itself. Massachusetts requires that one-quarter of the whole cost of a system shall be paid from general taxation and not over two-thirds from rentals. The system in Brockton, which is one of the oldest, if not the oldest, in the country, contemplated that one-quarter of the whole cost of the system be paid from general taxation, one-quarter from assessment, and one-half from rentals. That proportion has been applied, as nearly as possible, for the thirty-five years of the operation of the Brockton Sewerage System.

The present rate of rental at Brockton is 15 cents per 100 cu. ft. of water entering the sewer, based upon meter readings of the water department. The rate has been as high as 30 cents and was as low as $12^1/_2$ cents just previous to the World War.

Twenty-six Massachusetts cities and towns have sewage treatment works. Eleven out of twenty that replied to a questionnaire stated that they had no form of rental whatever. One of these contemplates its adoption. Eight of the nine that collect rentals base their collection on meter readings. The other one makes a charge per fixture. Most of

the departments have a minimum yearly charge of at least $5.00. The rates per cubic foot vary widely in the several communities.

In conclusion, let it be said that a method of financing a sewerage system that includes rentals has been given small consideration, apparently, throughout the country; although many engineers and lawyers, as well as other citizens, have approved of the principle involved. It has much merit as an equitable method of dividing costs, provided it is used with other methods, and preferably in conjunction with both assessment and general taxation.

Sewage Companies. K. IMHOFF. Address to a meeting of Chief Technical Officials of German Cities (Technische Oberbeamter deutscher Städte) in Leipzig, Sept. 3, 1930.—The construction of a large number of small treatment works can in many cases be avoided by the formation of sewage companies. The author deals with the necessary powers of such companies, the objections, including over-organization and inflexibility, which can be raised against their formation, and the conditions under which separate undertakings are more satisfactory. Before a company is formed, the purely economic advantages of the proposal must be clear. These may include not only saving in direct cost but the possible preservation of a river for water supply and the removal of nuisance. The value of the preservation of the purity of a river from other points of view, such as health, fishing and sport, is more difficult to assess. It must be remembered that the work of such a company will diminish after the first few years and over-organization and excessive staffs must be avoided. Large districts under a company should be divided up, each division being under an engineer with the most complete responsibility and power possible.—Abs. No. **63,** *British Summary of Current Literature, Water Pollution Research,* Vol. IV, 1 (January, 1931).

Report of Committee on Sewage Plant Records*

Reasons for Sewage Plant Records.—The subject of sewage plant records is one that is highly important from the standpoint of the operator, of the public and of supervising authorities. It is appalling to consider the vast sums of public money expended for sewage disposal plants for which no substantial amount of operating data is available. Such highly important and basic items as the quantity and character of the sewage treated, as determined by flow measurements and analyses of sewage solids, are not on record for many plants. Moreover, information as to what the plant is accomplishing in the way of removal of putrefactive solids is nowhere available to the public whose funds maintain the plant. Nothing can be intelligently handled unless its quality and quantity are known.

Your committee has listed below the various objectives to be attained with such records since the consideration of these objectives must be the basis for this report.

1. An indication to the operator or local official in charge that the plant is or is not functioning effectively.
2. Stimulation of the operator to pay increased and more intelligent attention to plant processes.
3. The collection of data helpful to the operator in working out improvements.
4. The assembling of data which may prove of value in protecting the community in lawsuits because of alleged pollution or nuisance.
5. A statement for the public to indicate the manner of operation of the plant and to show that the public is receiving adequate returns for money expended.
6. The accumulation of data for the use of state or other supervisory officials, to indicate the exact manner of operation and to furnish a basis for judging the effectiveness of changes in the past or suggestions for the future.
7. A guide for consulting engineers called upon to design changes or additions to the sewage plant.

Some of the points enumerated might be enlarged upon to include other more or less indirect benefits. For example, under "6," information may be accumulated which may not benefit the particular plant but would increase materially the general scientific knowledge of certain phases of sewage treatment. Under "7," flow records may indicate amounts of ground-water infiltration or surface-water entrance which might affect sewer construction. These indirect benefits could be extended indefinitely.

* *New England Sewage Works Association. Presented at 1930 Fall Meeting, Fitchburg, Mass., Oct. 15, 1930.*

Types of Plants to Be Considered.—Your committee recognizes the difficulty of drawing up suggested forms for records because of variations in the sizes and types of plants. They are particularly impressed with the need for suggestions to the operator of the small plant. Large plants are usually under the supervision of a trained chemist qualified to prepare and keep adequate records. Of course, both large and small plants should be provided with proper equipment to furnish such records.

Your committee feels that it should confine its considerations to basic records. Such records can be enlarged and extended by the operator of the large plant to suit his particular needs.

Periods of Time for Recording.—One objection to many record forms is that they include questions to be answered daily or monthly, whereas the answers are unvaried for a particular plant from year to year. This brings up the problem of daily, weekly, monthly or yearly records. After careful consideration, your committee has decided to recommend that operating data sheets be drawn up covering each day of every week. This would mean 52 sheets of weekly averages each year. One or two days would, of course, be carried over each year into the following year. The only confusion that might arise from the adoption of this program would seem to be in the case of plants where the custom has been, for example, to composite samples for analysis on a monthly basis. If this compositing were continued on the new basis with only daily, weekly and yearly records, it would be desirable to composite over a four-week period instead of a monthly period so as to have things uniform. This would mean that thirteen four-week composites would ignore the one or two extra days at the end of each year but they would be insignificant. Of course, there is nothing to prevent the continuance of monthly analytical records, if desired, even if the scheme here recommended were adopted.

In addition, your committee has presented a general data form covering a tabulation of the design and yearly operating summary. This would be particularly useful for the annual report of the plant operator.

Details of Recommended Records.—Rather than draw up one elaborate form intended to apply to all plants, your committee presents in Appendix "A" of this report, a series of general data sheets covering a tabulation of the design and yearly operating summary for each of the devices and treatment processes listed below and, in Appendix "B," a series of weekly operating sheets tabulated on a daily basis for each of the same devices and processes:

1. Racks or coarse bar screens (openings exceeding 0.5 inch)
2. Grit chambers
3. Skimming-detritus tanks
4. Fine screens

5. Plain sedimentation tanks
6. Separate sludge-digestion tanks
7. Imhoff tanks
8. Septic tanks
9. Sludge disposal, including mechanical drying and sand-bed drying
10. Dosing tanks
11. Contact filters
12. Trickling filters
13. Secondary-settling tanks
14. Sand filters
15. Activated sludge
16. Chlorination

To draw up forms for any particular plant, it is necessary only to pick out the particular processes used and to combine the forms suggested in the appendix for the particular processes with the general data presented for all plant processes. It is realized, of course, that some changes in the forms will undoubtedly be necessary in order to make them applicable to particular plants.

In drawing up these forms, your committee has been actuated by a desire to avoid too great detail and at the same time to include sufficient data to cover most of the important points. For example, under "construction cost" and "operating cost," it would be helpful if the sewer superintendent or operator could divide these up on a "per million gallon" basis and also make subdivisions into power, labor, fuel, repairs, etc., although this has not been done in these tabulations. Under "analytical determinations," it is realized that the operator of a small plant would probably be forced to limit himself to such simple field tests as "settleable solids" and perhaps the somewhat antiquated "relative stability" test. However, the analytical determinations listed present practically all of the determinations which could and should be made by a well-equipped laboratory.

Forms for Records.—Printed forms on good quality paper are most desirable. It may be worth while to start in with mimeographed sheets for a short period of time so as to try out the forms in actual practice before going to the expense of having them printed.

It is suggested that, where possible, the left sides of the sheets be punched with two or three holes so that the sheets may be kept in a loose-leaf ring folder. They can then be removed from the folder when desired and permanently bound or tied up for future reference. A convenient size for records seems to be $8\frac{1}{2}$ inches by 11 inches and it is recommended that this size be used. Records should best be recorded in indelible pencil.

Where it is desired to have additional copies of records to send to state

authorities or consulting engineers, it would seem that the most satisfactory procedure would be to have additional copies typed in the office of the superintendent, if possible. If it should be desired to make carbon copies with pencil in the field, it would probably be necessary to make up a special pad of forms.

Summary

Your committee presents this report in the hope that it will stimulate sewage-plant operators to keep records. The principal aims of this report are: (1) to present the needs for sewage plant records and (2) to summarize sufficiently detailed basic data as suggestions for the sewage-plant operator, so that he may readily draw up record forms for his particular plant. No attempt has been made to explain the reasons for the inclusion of each separate item in the suggested detailed record forms presented herewith, since this would result in an almost interminable report. It is realized that conditions vary and it is suggested that the plant operator, possibly aided in some cases by a supervisory consulting engineer or a supervisory state agency, draw up from the data presented a single simplified form containing the significant operating data for his particular plant. Elaborate records would naturally be more practical for large plants than for small ones.

It may be said frankly that the careless operation of hundreds of sewage treatment plants in this country is a matter of discredit to the officials in charge of these plants or to those who fail to appropriate necessary funds for the careful upkeep of the property in which they have invested heavily. The operator or sewage works superintendent should be made to do his part by keeping adequate records.

WARREN J. SCOTT, *Chairman*
JULIUS W. BUGBEE
E. SHERMAN CHASE
ROY S. LANPHEAR
EDWARD WRIGHT

APPENDIX A

General Data Compiled for Yearly Report Form for All Types of Plants

(In Addition to Which Detailed Data Forms Follow for Specific Plant Processes)

Design and Construction

1. Type of plant
2. Date of start of operation
3. Extent and date of enlargements
4. Basis of design (flow and population)
5. Approximate plant cost

Sewage Flow

6. Estimated population served
7. Total sewage flow treated for year
8. Daily discharge treated per year; avg.; max.; min.
9. Amount of sewage by-passed around various plant processes
10. Effluent discharged to
11. Industrial wastes affecting sewage treatment

Total Operating Cost

12. Total annual operating cost (exclusive of fixed charges)
    (*a*) Renewal and repairs
    (*b*) Power
    (*c*) Labor
    (*d*) Supplies

Racks

1. Type
2. Spacing—clear opening
3. Quantity of flow handled, current year
4. Rack rakings—cu. ft.
    (*a*) Total
    (*b*) Per m. g.

Grit Chambers

1. Type and number
2. Dimensions
3. Estimated avg. velocity of flow, ft. per sec.
4. Depth of flow (including grit space); avg.; max.
5. Depth allotted to grit space
6. Method of cleaning
7. Disposal of grit
8. Quantity of flow handled, current year
9. Volume of grit removed, cu. ft.
    (*a*) Total
    (*b*) Per m. g.
    (*c*) Weight per cu. ft., avg.
    (*d*) Per cent of solids, avg.
10. Construction cost
11. Operating cost

Fine Screens

1. Type and number
2. Size
3. Speed (r. p. m.)
4. Size of apertures (inches)
5. Size of motors
6. Quantity sewage screened (current year)
7. Power consumed per m. g. (k. w. h.)
8. Loss of head; avg.; min.
9. Quantity of screenings—cu. ft.
    (*a*) Total
    (*b*) Per m. g.
    (*c*) Weight per cu. ft., avg.
    (*d*) Per cent of solids, avg.
10. Construction cost
11. Operating cost

Skimming-Detritus Tanks

1. Type and number
2. Dimensions
3. Capacity in m. g. d.; avg.; max.
4. Method of operation
5. Detention periods; avg.; min.
6. Method of skimming
7. Disposal of skimmings
8. Quantity of flow handled, current year
9. Quantity of skimmings removed, cu. ft.
    (*a*) Total
    (*b*) Per m. g.
    (*c*) Weight per cu. ft., avg.
    (*d*) Per cent solids, avg.
10. Quantity of detritus removed, cu. ft.
    (*a*) Total
    (*b*) Per m. g.
    (*c*) Weight per cu. ft., avg.
    (*d*) Per cent solids, avg.
11. Construction cost
12. Operating cost

Plain Sedimentation Tanks

1. Type and number of tanks
2. Dimensions and capacities
3. Quantity of sewage settled, current year
4. Period of detention; avg.; min.
5. Construction cost
6. Operating cost

Separate Sludge Digestion Tanks

1. Type and number of tanks
2. Dimensions and capacities
3. Cu. ft. of sludge storage per capita served
    (*a*) Design basis
    (*b*) Operating basis
4. Type of agitation equipment, if any
5. Type of sludge pumps, if any
6. Type of heating apparatus, if any
7. Yearly measurement of cu. ft. of gas burned per 1000 population served
8. Yearly amount of fuel burned per 1000 population served
9. Length of sludge digestion; avg.; max.; min.

10. Frequency of sludge removal
11. Average temperature of sludge
    (*a*) Winter
    (*b*) Summer
12. Construction cost
13. Operating cost

Imhoff Tanks

1. Type and number of tanks
2. Overall dimensions
3. Capacities of sedimentation compartments
4. Sludge storage space
    (*a*) Total
    (*b*) Per capita, design basis
    (*c*) Per capita, operating basis
5. Gas vent area
    (*a*) Per cent of tank area
    (*b*) Sq. ft. per cu. ft. of sludge storage space
6. Quantity sewage settled, current year
7. Period of detention; avg.; min.
8. Quantity of scum removed
9. Disposal of scum
10. Frequency of sludge removal, avg.
11. Construction cost
12. Operating cost

Septic Tanks

1. Type and number of tanks
2. Dimensions and capacities
3. Type of roof
4. Bottom slope
5. Quantity of sewage handled, current year
6. Period of detention; avg.; min.
7. Quantity of scum removed
8. Disposal of scum
9. Construction cost
10. Operating cost

Sludge Disposal

1. Quantity of wet sludge produced
    (*a*) Total
    (*b*) Gallons per m. g. of sewage
    (*c*) Per cent of solids
    (*d*) Lbs. of dry solids per m. g. of sewage
2. Method of disposal
3. Sludge conditioning
4. Type of dewatering equipment
5. Quantity of dewatered sludge
    (*a*) Total
    (*b*) Cu. ft. per m. g. of sewage
    (*c*) Per cent of solids
    (*d*) Lbs. of dry solids per m. g. of sewage
6. Type of drying equipment
7. Quantity of dried sludge
    (*a*) Total
    (*b*) Cu. ft. per m. g. of sewage
    (*c*) Per cent of solids
    (*d*) Lbs. of dry solids per m. g. of sewage
8. Disposal of dried sludge
9. Construction cost
10. Operating cost

Dosing Tanks

1. Number of tanks
2. Tanks open or covered
3. Effective capacity of each tank
4. Number and sizes of siphons
5. Operating head; max.; min.
6. Filling period, avg.
7. Discharge period, avg.

Contact Filters

1. Number and area of filter units
2. Depth, kind and size of filter material
3. Percentage of voids
4. Type of underdrainage system
5. Quantity of sewage treated, current year
6. Avg. time of contact
7. Avg. time of resting
8. Avg. daily rate of dosage per foot of filter depth in gals. per acre
9. Length of service of filter medium in use
10. Replacement or washing of filter medium
11. Construction cost
12. Operating cost

Trickling Filters

1. Number and area of filter units
2. Depth, size and kind of filter material
3. Type of distribution system
4. Type of underdrainage system

5. Quantity sewage filtered, current year
6. Average daily rate of dosage per foot of filter depth in gals. per acre
7. Frequency of flushing distribution system
8. Frequency of flushing drainage system
9. Frequency of flooding filters
10. Construction cost
11. Operating cost

Secondary-Settling Tanks

1. Type and number of tanks
2. Dimensions and capacities
3. Quantity of sewage settled, current year
4. Period of detention; max.; min.
5. Frequency of sludge removal
6. Disposition of sludge
7. Construction cost
8. Operating cost

Intermittent Sand Filters

1. Number and area of filter units
2. Type of distribution system
3. Source and characteristics of filter sand
4. Average depth of sand layer
5. Type of underdrainage system
6. Quantity of sewage filtered, current year
7. Average daily rate of dosage in gals. per acre
8. Theoretical depth of liquid applied to filters in one dose
9. Average filter dosing schedule
10. Construction cost
11. Operating cost

Activated Sludge

(For Preliminary Treatment, see pertinent data forms preceding.)

1. Aeration tanks
   - (*a*) Type and number
   - (*b*) Dimensions and capacities
   - (*c*) Type of bottom
   - (*d*) Types of diffusers
   - (*e*) Ratio of gross diffuser area to tank area
   - (*f*) Average aeration period, hrs.
   - (*g*) Average return sludge allowance, per cent of sewage flow
   - (*h*) Mechanical aerator
     1. Type
     2. Power requirements
2. Channel aeration
   - (*a*) Feed channels
   - (*b*) Mixed-liquor channels
3. Sedimentation tanks
   - (*a*) Type and number
   - (*b*) Dimensions and capacities
   - (*c*) Avg. and min. periods of sedimentation, including returned sludge
     1. Corresponding capacities per day per sq. ft.
4. Return sludge (see also "Sludge Disposal" data)
   - (*a*) Per cent of solids
   - (*b*) Method of drawing
   - (*c*) Method of returning
   - (*d*) Re-aeration period in hours
5. Air supply
   - (*a*) Number and type of compressors
   - (*b*) Capacity per unit and total, cu. ft. per min.
   - (*c*) Initial pressure
   - (*d*) Volume supplied, cu. ft. per gal. of sewage
     1. Total
     2. Aeration tanks
     3. Re-aeration tanks
     4. Air lift
   - (*e*) Type of air-cleaning equipment
6. Construction cost
7. Operating cost
8. Revenue received from sale of sludge

Chlorination

1. Type of chlorination equipment
2. Lbs. of chlorine used, current year
   - (*a*) Operating days, chlorine used
   - (*b*) Lbs. per m. g.; avg.; max.; min.
3. Method of control of chlorine dosage
4. Construction cost
5. Operating cost

APPENDIX B

Daily Operating Data for All Types of Plants

(Detailed Additional Daily Operating Sheets Follow for Individual Processes)

Data in Appendix B to be recorded in columns after each item, from Sunday through Saturday, and each weekly sheet to be dated.

1. Weather (fair, cloudy, rain)
   - (*a*) Direction of wind
   - (*b*) Inches rainfall, if available
2. Plant odors
3. Sewage flow
   - (*a*) Total daily
   - (*b*) Max. flow rate
   - (*c*) Min. flow rate
4. Amount of flow by-passed
5. Analytical determinations of sewage
   - (*a*) Settleable solids, cc. per litre D
   - (*b*) Suspended solids, p. p. m., D or W
   - (*c*) pH, S
   - (*d*) Dissolved oxygen, p. p. m., S
   - (*e*) Biochemical ox. demand, p. p. m., D
   - (*f*) Ox. consumed, p. p. m., W
   - (*g*) Chlorides, p. p. m., W
   - (*h*) Free ammonia, p. p. m., W
   - (*i*) Organic nitrogen, p. p. m., W
   - (*j*) Nitrites, p. p. m., W
   - (*k*) Nitrates, p. p. m., W
   - (*l*) Alkalinity, p. p. m., S
6. Temperature of sewage
7. Hours at plant by operator
8. Extra help employed

NOTE: D = Daily determinations; W = Weekly composite determinations; S = Special tests.

Operating Data for Racks, Fine Screens, Grit Chambers, Skimming-Detritus Tanks

Racks

1. Number of times cleaned
2. Cu. ft. of rack rakings

Fine Screens

1. Screens in use
2. Daily flow screened, m. g.
   - (*a*) Max. rate
3. Quantity of screenings, cu. ft.
   - (*a*) Total
   - (*b*) Per m. g.
   - (*c*) Weight per cu. ft., avg.
   - (*d*) Avg. per cent solids
4. Screens cleaned

Grit Chambers

1. Grit chambers in use
2. Depth of flow, avg.
   - (*a*) Max.
3. Grit removed
   - (*a*) Vol. in cu. ft., total
     1. Per m. g.
   - (*b*) Wt. per cu. ft., avg.
   - (*c*) Avg. per cent solids

Skimming-Detritus Tanks

1. Tanks in use
2. Skimmings removed
   - (*a*) Vol. in cu. ft., total
     1. Per m. g.
   - (*b*) Wt. per cu. ft., avg.
   - (*c*) Avg. per cent solids
3. Detritus removed
   - (*a*) Vol. in cu. ft., total
     1. Per m. g.
   - (*b*) Wt. per cu. ft., avg.
   - (*c*) Avg. per cent solids

Plain Sedimentation Tanks

1. Daily flow settled, m. g.
2. Tanks in use
3. Period detention
   - (*a*) Avg.
   - (*b*) Min.
4. Sludge collecting equipment
   - (*a*) Hours operated
     Tank no.
     Tank no.
   - (*b*) Sludge removed from
     Tank no.
     Tank no.
5. Scum removal
   Tank no.
   Tank no.
6. Analytical determinations

(*a*) Settleable solids, cc. per litre, D
Tank no.
Tank no.
(*b*) Suspended solids, combined effluent, p. p. m., D or W
(*c*) B. O. D., combined effluent p. p. m., D
(*d*) Chlorides, combined effluent, p. p. m., W
(*e*) Oxygen consumed, combined effluent, p. p. m., W

NOTE: D = Daily determinations; W = Weekly composite determinations.

Separate Sludge Digestion Tanks

1. Sedimentation tank sludge pumped from Tank no.
   To digestion Tank no.
   Hours pumping
2. Hours operation of agitating equipment
   Tank no.
   Tank no.
3. Hours recirculation pumping in
   Tank no.
   Tank no.
4. Sludge pumped from digestion tank no.
   To digestion tank no.
   Hours pumping
   To inlet sedimentation tanks
   Hours pumping
   To sludge beds
   Hours pumping
5. Pounds chemical added
   Tank no.
   Tank no.
6. Hours gas heater operated
   Gas meter reading
7. Hours coal heater operated
   Amount coal used
8. Average temperature air
9. Average temperature heating water
10. Temperature sludge
    Tank no.
    Tank no.
11. pH
    Tank no.
    Tank no.

Imhoff Tanks

1. Daily flow settled, m. g.
2. Number of tanks in use
3. Direction of flow
   Tank no.
   Tank no.
4. Period detention
   (*a*) Avg.
   (*b*) Min.
5. Flow chambers skimmed
   Tank no.
   Tank no.
6. Channels cleaned, aprons squeegeed, slot cleared
   Tank no.
   Tank no.
7. Gas vent solids broken up
   Tank no.
   Tank no.
8. Valves operated
9. Sludge drawn
   (*a*) Tank and hopper nos.
10. Inches scum, N. or W. ends of gas vents
    Tank no.
    Tank no.
11. Inches scum, S. or E. ends of gas vents
    Tank no.
    Tank no.
12. Feet sludge, N. or W. ends of tanks
    Tank no.
    Tank no.
13. Feet sludge, S. or E. ends of tanks
    Tank no.
    Tank no.
14. Analytical determinations
    (*a*) Settleable solids, cc. per liter, D
    Tank no.
    Tank no.
    (*b*) Suspended solids, combined effluent, p. p. m., D or W
    (*c*) B. O. D. combined effluent, p. p. m., D
    (*d*) Chlorides, combined effluent, p. p. m., W
    (*e*) Oxygen consumed, combined effluent, p. p. m., W

NOTE: D = Daily determinations; W = Weekly composite determinations.

Septic Tanks

1. Daily flow settled, m. g.
2. Number of tanks in use
3. Period detention
   (*a*) Avg.
   (*b*) Min.
4. Channels cleaned
5. Scum broken up in Tank no.
6. Sludge drawn from Tank no.
7. Scum removed from Tank no.
8. Tank no.
   Inches inlet scum
   Inches outlet scum
   Inches inlet sludge
   Inches outlet sludge
9. Tank no.
   Inches inlet scum
   Inches outlet scum
   Inches inlet sludge
   Inches outlet sludge
10. Analytical determinations
   (*a*) Settleable solids, cc. per litre, D
   (*b*) Suspended solids, combined effluent, p. p. m., D or W
   (*c*) B. O. D., combined effluent, p. p. m., D
   (*d*) Chlorides, combined effluent, p. p. m., W
   (*e*) Oxygen consumed, combined effluent, p. p. m., W

NOTE: D = Daily determinations; W = Weekly composite determinations.

Sludge Disposal on Sand Beds

1. Quantity wet sludge drawn
   (*a*) Per cent solids
   (*b*) Pounds dry solids
   (*c*) Per cent volatile solids
2. Sludge beds dosed, inches
   Bed no.
   Bed no.
3. Dried sludge removed from beds, inches
   Bed no.
   Bed no.
4. New sand added, inches, to
   Bed no.
   Bed no.

NOTE: See also "Mechanical dewatering and drying" under "Activated Sludge."

Dosing Tanks

1. Number of dosing tanks in use
2. Siphon discharges
3. Dosing tanks cleaned
   Tank no.
   Tank no.

Contact Filters

1. Daily quantity filtered, m. g.
2. Number of filters in use
3. Number of filter doses
4. Avg. time filling
5. Avg. time resting
6. Avg. time discharge
7. Analytical determinations
   (*a*) Settleable solids, effluent, cc. per litre, D
   (*b*) Suspended solids, p. p. m., D or W
   (*c*) B. O. D., p. p. m., D
   (*d*) *Nitrites, p. p. m., D or W
   (*e*) *Nitrates, p. p. m., D or W
   (*f*) *Dissolved oxygen, p. p. m., D or W
   (*g*) Free ammonia, p. p. m., W
   (*h*) Organic nitrogen, p. p. m., W
   (*i*) Chlorides, p. p. m., W
   (*j*) Relative stability, D

* Individual unit effluents, if desired.

NOTES: Make special record of removal or washing of filter medium. D = Daily determinations; W = Weekly composite determinations.

Trickling Filters

1. Daily quantity filtered, m. g.
2. Number of filters in use
3. Number of filter doses
4. Number of nozzles cleaned
   (*a*) In filter nos.
5. Filter nos. flooded
6. Distribution systems flushed, filter nos.
7. Drainage systems flushed, filter nos.
8. Analytical determinations
   (*a*) Settleable solids, effluent, cc. per liter, D
   (*b*) Suspended solids, p. p. m , D or W
   (*c*) B. O. D., p. p. m., D
   (*d*) *Nitrites, p. p. m., D or W

(*e*) *Nitrates, p. p. m., D or W
(*f*) *Dissolved oxygen, p. p. m., D or W
(*g*) Free ammonia, p. p. m., W
(*h*) Organic nitrogen, p. p. m., W
(*i*) Chlorides, p. p. m., W
(*j*) Relative stability, D

* Individual unit effluents, if desired.

NOTE: D = Daily determinations; W = Weekly composite determinations.

Secondary-Settling Tanks

1. Tanks in use
2. Daily flow settled, m. g.
3. Period detention
   (*a*) Avg.
   (*b*) Min.
4. Sludge collecting equipment
   (*a*) Hours operated
   Tank no.
   Tank no.
   (*b*) Sludge removed from
   Tank no.
   Tank no.
5. Analytical determinations
   (*a*) Settleable solids, effluent, cc. per litre, D
   (*b*) Suspended solids, p. p. m., D or W
   (*c*) B. O. D., p. p. m., D
   (*d*) *Nitrites, p. p. m., D or W
   (*e*) *Nitrates, p. p. m., D or W
   (*f*) *Dissolved oxygen, p. p. m., D or W
   (*g*) Free ammonia, p. p. m., W
   (*h*) Organic nitrogen, p. p. m., W
   (*i*) Chlorides, p. p. m., W
   (*j*) Relative stability, D

* Individual unit effluents, if desired.

NOTE: D = Daily determinations; W = Weekly composite determinations.

Intermittent Sand Filters

1. Daily quantity filtered, m. g.
2. Number of beds in use
3. Number of beds covered with sewage
4. Number of beds dry
5. Number of beds scraped
6. Number of beds clean
7. Number of doses
   If no siphon dosing chamber:
   Flow turned on to filter no. at
   Flow turned off filter no. at
8. Analytical determinations
   (*a*) Settleable solids, effluent, cc. per litre, D
   (*b*) Suspended solids, p. p. m., D or W
   (*c*) B. O. D., p. p. m., D
   (*d*) *Nitrites, p. p. m., D or W
   (*e*) *Nitrates, p. p. m., D or W
   (*f*) *Dissolved oxygen, p. p. m., D or W
   (*g*) Free ammonia, p. p. m., W
   (*h*) Organic nitrogen, p. p. m., W
   (*i*) Chlorides, p. p. m., W
   (*j*) Relative stability, D
   (*k*) *Iron, p. p. m., W

* Daily analytical determinations should be made with a view to testing efficiency of individual filter units, when necessary.

NOTE: D = Daily determinations; W = Weekly composite determinations.

Activated Sludge

1. Daily quantity treated, m. g.
2. Aeration tanks
   (*a*) Number of tanks in use
   (*b*) Return sludge flow, m. g. d.
   (*c*) Mixed liquor flow, m. g. d.
   (*d*) Per cent settling solids (½ hr.) in mixed liquor
   (*e*) Aeration period, hours
3. Air supply
   (*a*) Quantity, cu. ft. per day
      1. Total
         (*a*) Cu. ft. per gal. sewage
      2. Aeration tanks
      3. Channels
      4. Air lift
   (*b*) Power used, k. w. hours
4. Mechanical dewatering and drying
   (*a*) Quantity wet sludge dewatered
      1. Moisture
   (*b*) Kind and quantity of conditioning chemicals used

(c) Quantity of sludge cake
  1. Moisture
(d) Quantity of heat dried sludge
  1. Moisture
(e) Fuel required
(f) Power—sludge dewatering
(g) Power—sludge drying

5. Analytical determinations (final effluent)
(a) Settleable solids, cc. per litre, D
(b) Suspended solids, p. p. m., D or W
(c) B. O. D., p. p. m., D
(d) *Nitrites, p. p. m., D or W
(e) *Nitrates, p. p. m., D or W
(f) *Dissolved oxygen, p. p. m., D or W
(g) Free ammonia, p. p. m., W
(h) Organic nitrogen, p. p. m., W
(i) Chlorides, p. p. m., W
(j) Relative stability, D

* Individual unit effluents, if desired.

NOTES: D = Daily determinations; W = Weekly composite determinations. See also Sludge Disposal on Sand Beds, and Screening and Settling Tank processes.

Chlorination

1. Daily quantity chlorinated, m. g.
2. Pounds of chlorine applied
(a) Total
(b) Per m. g.
3. Residual chlorine tests
4. Analytical determinations
(a) Bact. count in 24 hrs., $37\frac{1}{2}$° C.
(b) Quantity of *B. Coli*

Stream Pollution

Impounding Reservoirs as a Substitute for Biological Sewage Treatment Works in the Ruhr District*

By Karl Imhoff**

Translated by Gordon M. Fair***

When the natural purification processes operative in streams are called upon to digest within limited river stretches the organic wastes discharged into the flowing waters, the self-purification accomplished depends upon the time of flow. Streeter and Phelps have given us excellent examples of this fact in their studies of the Ohio River.[1] Thus, they have computed for a time of flow of ten days the changes in the dissolved-oxygen content of the river water below Pittsburgh, illustrated in Figure 1. The curve relates to low-water stages, summer temperatures and an initial oxygen demand of the mixed sewage and river water amounting to 25 p. p. m. At the point of pollution the dissolved-oxygen content of the river water is 9 p. p. m. or 90 per cent of saturation (10 per cent saturation deficit). Within two days this value sags to 25 per cent, after which it rises slowly, a value of 90 per cent being approximately reached after ten days.

The increase in oxygen concentration, which is the best index of the progressive self-purification during the time of flow, shows that natural purification is augmented as the time of flow is lengthened. If, therefore, the river waters are impounded and the time of flow thereby increased, it is possible to attain the same effect in a shorter river stretch. Thus an impounding reservoir, or artificial lake, acts in a similar manner to a sewage-treatment plant in maintaining the cleanliness of a stream. The treatment plant reduces the pollutional load in the stream by reducing the oxygen demand of the waste waters, or the deoxygenation of the stream. The impounding reservoir acts in an opposite manner by increasing the reoxygenation or reaeration of the waters.

Impounding reservoirs for sewage treatment are being constructed in the Ruhr valley near Essen by the Ruhrverband. The Ruhr River carries

* *Presented at the 59th Annual Meeting of the American Public Health Association, Ft. Worth, Texas.*

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[1] A Study of the Pollution and Natural Purification of the Ohio River, Public Health Bulletin 146, February, 1925.

the sewage from 1,440,000 people. At the same time, however, the river supplies water to this population and to an additional two million people in neighboring communities—a total of 3.5 million people. The water works reduce the amount of water carried by the river to such an extent that during low stages the stream flow is less at the mouth of the Ruhr than in its middle course.

At the present time the Ruhrverband operates sixty-five sewage-treatment works, serving the inhabitants as follows:

Population served by sedimentation units only	730,000
Population served by biological treatment works	140,000
Population not connected to treatment works	570,000
Total population in the Ruhr district	1,440,000

During the very dry summer of 1929, the treatment plants of the Ruhrverband were subjected to a severe test. The stream flow of the Ruhr

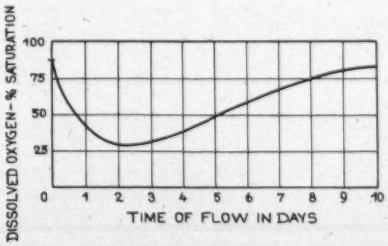

FIG. 1.—Estimated Dissolved-Oxygen Content of the Ohio River below Pittsburgh at Low-Water Stages and for Summer Temperatures, Assuming an Initial Oxygen Demand of 25 P. P. M. and an Initial Oxygen Saturation Deficit of 1.0 P. P. M. or 10 Per Cent. (After Streeter and Phelps, 1925.)

was extremely low during the months of July, August and September. During September, 1929, it was so reduced that the water drawn from the river was equal to or greater than the run-off of the Ruhr. For three weeks the stream discharged no water into the Rhine River, to which it, the Ruhr, is tributary. During these three weeks the Ruhr waters consisted chiefly of sewage that was used over and over in repeated cycles.

Figure 2 shows the run-off values observed along the Ruhr on September 12, 1929, in the 90-kilometer (56-mile) stretch beginning at the point where the river leaves Lake Hengstey (Hengstey Reservoir) and ending at its mouth in the Rhine. The runoff was about 8 cu. m. per second (280

c. f. s.) below Lake Hengstey and minus 1 cu. m. per second (35 c. f. s.) at the river mouth (the negative flow was supplied by pumpage from the Rhine on the following day). The degree of purity of the Ruhr water is indicated in Figure 2 by its oxygen content. In general the oxygen saturation value amounted to between 40 and 60 per cent. The condition of the river, therefore, was somewhat precarious. Nevertheless, the self-purification of the stream was still adequate in combination with the effect of the existing sewage-treatment works. Destruction of fish life was not observed. The water works could maintain full operation and the drinking water drawn was continuously good.

After the experiences of 1929 the Ruhrverband is determined to improve the conditions still further. For this purpose seven impounding reservoirs are to be added to the existing one, Lake Hengstey. A second reservoir, Lake Harkort, will be placed in operation toward the end of 1930. The remaining six reservoirs will follow in the next few years. The capacity of all eight reservoirs totals about 30 million cubic meters (about one billion cubic feet) and their surface area about 12 sq. km. (4.6 sq. miles).

The expected effect of the new reservoirs may be calculated from the time of flow. This has been done in Figure 2, in which is given the time of flow for September 12, 1929, together with the time of flow based upon completion of the seven new reservoirs and computed for the same river discharge. The "calculated time of flow" is dealt with. This is obtained by dividing the volume of water in a given river stretch by the rate of discharge. In September, 1929, for example, the time of flow from Lake Hengstey to the last source of pollution at Kettwig amounted to eighteen days. In this stretch the sources of pollution and the locations of water intakes are arrayed at short intervals so that in each instance a time of flow of only one to, at most, two days intervenes between a point of pollution and a water works; hence the low oxygen content in this stretch. At the mouth of the Ruhr, however, where the water was supersaturated with oxygen (also after standing for twenty-four hours), a time of flow is computed of seventy-nine days from Hengstey, or sixty-one days from the last point of pollution at Kettwig. That explains the exceptionally great self-purification in the stretch near the mouth of the river.

The future time of flow, as recorded in Figure 2, is appreciably longer. For example, the value for the stretch from Hengstey to Witten, which was two days in 1929, will be raised to nine days. From Hengstey to Essen it will be sixty-three days instead of twelve and from Hengstey to Kettwig eighty-four days instead of eighteen. In general, the future time of flow between a source of strong pollution and the next water works will be increased on an average to one week, as compared with one or two days in 1929. Should low flows like those of 1929 again be encountered, the

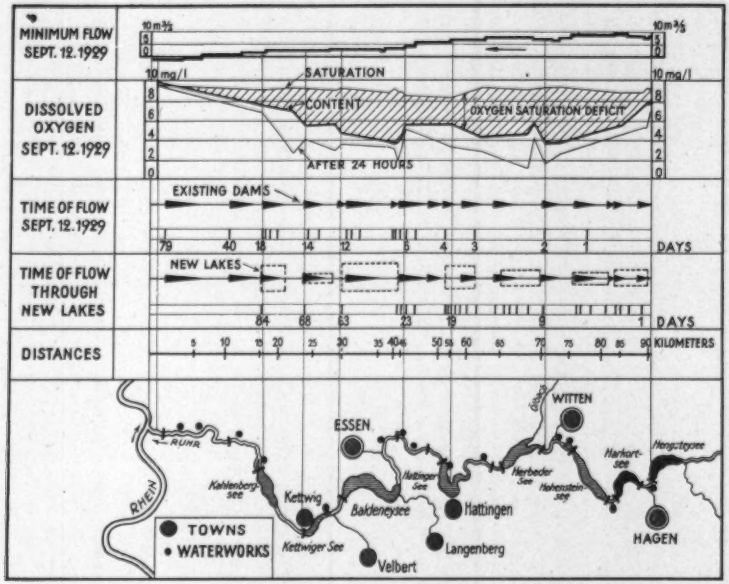

FIG. 2.—The Time of Flow of the Ruhr River between Hengstey and Kahlenberg Will Be Raised from 18 to 84 Days during Extreme Low Water by Constructing Seven New Impounded Reservoirs. The Oxygen Saturation, It Is Estimated, Will Be Approximately 100 Per Cent, without Further Biological Treatment of Sewage, Instead of 40 to 60 Per Cent as in 1929

time of flow, according to calculation, will be sufficient to carry the oxygen saturation of the water to approximately 100 per cent in the full length of the Ruhr from Hengstey to the Rhine. This effect is expected from the new impounding reservoirs alone, without the construction of new sewage-treatment works.

Compared with sewage-treatment plants, the reservoirs possess the economic advantage that they are practically self-supported by the income from the coincident development of water power. The members of the Ruhrverband are, therefore, not taxed by their use. In addition, they offer great advantages for water sports and recreation, and are thus welcomed by the neighboring communities. So long as it is possible to develop reservoirs that provide the same effect as sewage-treatment works, the Ruhrverband will always prefer reservoirs. It is planned, therefore, to desist from building more biological treatment plants beyond those at present provided for 140,000 people.

There are two prerequisites to the construction of impounding reservoirs as a substitute for sewage-treatment plants:

1. The municipal sewage must be freed from sludge-forming solids as far as possible in sedimentation tanks. Otherwise sludge would accumulate on the reservoir bottom and putrefy in summer. The reservoirs, therefore, may well replace biological treatment, but not sedimentation.

2. In winter, the river must carry an adequate amount of water; for during cold weather natural self-purification is greatly reduced, also in reservoirs. Adequate dilution of the sewage by river water is then required. Both requirements are met in the Ruhr District.

Influence of Certain Water Conditions, Especially Dissolved Gases, on Trout. J. S. GUTSELL. *Ecology*, 1929, **1**, 77; *Chem. Abst.* (*U. S.*), 1929, **23**, 1960.—Experiments on brook, brown and rainbow trout were carried out. With the increased activity of soil bacteria as the warm season advanced the carbon dioxide content rose and oxygen content decreased. An oxygen content below 1.3 p. p. m. always caused death. Trout gradually accustomed to low oxygen contents could endure contents low enough to be fatal to trout from well-oxygenated water, but asphyxiation always occurred below 1.3 p. p. m. and partial asphyxiation and sluggishness between 1.3 and 2.5 p. p. m. Partially-asphyxiated trout recovered if moved to a water of as low oxygen content as 2.67 p. p. m. Carbon dioxide up to 28 p. p. m. was not markedly harmful and amounts up to 39 p. p. m. did not increase the ill effects of reduced oxygen. Provided the oxygen content was sufficient, trout were hardy to considerable variation in pH.—Abs. No. **116**, *British Summary of Current Literature, Water Pollution Research*, Vol. IV, 1 (January, 1931).

Editorial

Thermophilic Digestion

The digestion of sewage solids was considered to be a lengthy process some fifteen years ago. Imhoff tanks were designed to hold sludge for five or six winter months and even when proper ratios of ripe and fresh solids were maintained it was necessary to provide for this storage period. When insufficient ripe sludge was present the digestion time was much longer, and in cold separate digestion tanks, with unseeded sludge, the time might actually run into years, as indicated by the experimental evidence that storage for more than 800 days was required for digestion of Baltimore sludge without heat and without any seeding sludge or pH control. (THIS JOURNAL, **II**, p. 213, April, 1930.)

After laboratory studies in Germany had shown that digestion was delayed by acid fermentation and that true digestion was accompanied by methane production and an alkaline reaction of the medium, it became possible to diagnose the ailments of "sick" digestion tanks, and to prescribe, with some degree of scientific precision, remedies for the abnormal condition.

Notwithstanding this advance in knowledge, the progress of digestion was limited to the rates possible at the approximate temperature of the sewage, or in separate tanks, at even lower temperatures in winter. Although laboratory experiments by Bach, Sierp and Rudolfs demonstrated that artificial heating of the sludge was possible, with marked acceleration of the process, it was not until five or six years ago that heating of sludge was seriously considered for large digestion tanks. Separate tanks were well adapted for heating equipment, but even to date it has been found impracticable to heat the lower chamber of Imhoff tanks more than a few degrees, because of excessive losses of heat by convection currents through the open slot. Curves defining time of digestion at various temperatures are so well known as to require no more than brief reference. Considering 15° C. (59° F.) as the unit temperature, the time of digestion could be halved by increasing the temperature to 25° C. (77° F.) and still further reduced at 28° C. (82° F.), considered to be the optimum temperature until the last two years. The digestion curves showed an increasing time above 28° C., although higher temperatures were apparently not investigated thoroughly until Dr. Rudolfs began to become interested in thermophilic digestion. The first tests reported (*Ind. & Eng. Chem.*, **22**, p. 96, Jan., 1930) indicated that after an apparently inhibitory zone at

90° to 100° F. was passed, a bacterial flora might be built up at higher temperatures, ranging from 120° to 140° F., which would greatly accelerate the rate of digestion at 82° F., formerly considered the optimum. Later papers from the New Jersey station have led up to the most complete yet published, in this issue. The discussion by Dr. Rudolfs outlines the features and possibilities of this noteworthy advance in the technique of sludge disposal. He states that "If under ordinary (82° F.) temperature 50 to 60 per cent of the volatile matter is decomposed in 25 to 30 days, about 70 to 75 per cent is destroyed at 120° F. in 1 to 3 days."

It is reasonable to expect that some practical use will be made of this fact. The greatest need is for tests on a large scale and on various sludges. It is reported (*The Surveyor*, **78,** 555, Nov. 28, 1930) that small-scale experiments on thermophilic digestion have been made at Leeds, with inconclusive results. Dr. Ardern reports laboratory tests (this issue, page 146) with two types of sludge at Manchester. One type of sludge, from the Davyhulme Works, digested more poorly at 120° F. than at 80° F. Another type of sludge, containing purely domestic solids, digested more readily, although even in this case there was little improvement at 120° as compared with 80°.

Large-scale tests have been reported by Dr. Prüss (*The Surveyor*, **78,** 622, Dec. 19, 1930). He states that "In the Emschergenossenschaft, at Gelsenkirchen, we have experimented with thermophilic digestion in a digestion tank of about 20,000 cu. ft. capacity. This tank was operated for almost a year at a temperature of 48° C., and it was found, as in the case of Mr. Thompson's experiments (at Leeds), that the action was extraordinarily sensitive, and that the daily gas production varied inexplicably between wide limits. Since the Gelsenkirchen plant has to treat sewage containing a large admixture of coal sludge and also pickle from iron works, the sensitiveness of thermophilic sludge digestion rendered it necessary to abandon the experiments."

These experiences at Leeds, Manchester and Essen indicate that the character of sewage solids affects thermophilic digestion to a far greater degree than digestion at 82° F. When we know more about the optimum bacterial flora for high temperature digestion, and how to cultivate such a flora, it may be possible to overcome the toxic effect of industrial wastes.

A fact of outstanding interest in Dr. Heukelekian's work is that the most efficient flora must be built up by successive cultures, a procedure reminiscent of the accumulation of activated sludge. In fact, there is a rather close analogy between the acceleration of digestion by thermophilic sludge and the acceleration of oxidation by activated sludge. In 1916 the application of the activated-sludge process to sewage treatment on a large scale was somewhat dubious, but it had been demonstrated without question that the time required to nitrify sewage by artificial aeration

could be reduced from 2 weeks to 4 hours. Practical utilization of this fact was bound to follow. It is equally probable that in the next decade substantial practical development will be made of the fact that digestion can be accomplished in 2 days at 120° F. as compared with 30 to 35 days at 82° F. and 3 or 4 months in the absence of artificial heat.

Many practical requirements still remain to be worked out. Notwithstanding these requirements, the results reported by Drs. Heukelekian and Rudolfs in this issue, that digestion for 48 hours is sufficient at 120° F., that 90 per cent of the gas is liberated in the first 24 hours, that the sludge may be dense and with only a slight "cooked" odor, raise hopes that the problems of maintaining high temperatures, controlling toxic effects of industrial wastes and preventing scum formation may be conquered and that thermophilic digestion may develop into as great an improvement over digestion of unheated sludge as the activated sludge process is now an improvement over the earlier attempts to oxidize sewage by plain aeration.

Sludge Moisture

The moisture content of sludge undergoing digestion is the most important factor affecting the cost of sludge digestion tanks, whether two-story or separate. Twice as much capacity must be provided for sludge with 95 per cent moisture as for sludge with 90 per cent moisture. The various factors that affect sludge digestion, such as temperature, age, reaction and depth of tank, narrow down to the final consideration, from the standpoint of cost, of the capacity that must be provided to hold the sludge for the digestion period. This capacity is determined by the average moisture content.

In view of the importance of this fact, it is surprising that we have so little information concerning the moisture content of sludge at various depths in digestion tanks. Engineers who design digestion tanks must almost always make a good guess as to average moisture content, and usually opinions differ widely.

One of the most valuable papers ever published on this subject contains the observations of Dr. H. Blunk, Chief Engineer of the Emscher District, who visited the United States last summer. Dr. Blunk's paper was published six years ago, in *Gesundheits-Ingenieur*, Jan. 24, 1925. His discussion is noteworthy because it contains studies of various Imhoff tanks in Germany, with analyses of sludge at various depths, and a discussion of the reasons for differences in moisture content. Dr. Blunk concludes that the average moisture content depends upon the initial moisture content of the settled solids, the time of storage and the temperature.

Another outstanding contribution is Mr. Eddy's "Imhoff Tanks—Reasons for Differences in Their Behaviour," published in the *Proceedings of the American Society of Civil Engineers* for May, 1924. Mr. Eddy compared Inhoff tanks at Fitchburg, Plainfield, Rochester and Schenectady, and discussed, among other things, the reasons for the wide differences in the moisture content of the sludge at the four plants. He concluded, as did Dr. Blunk, that the character of the sewage solids, and the time and temperature of digestion are of primary importance.

Studies of the effect of depth have been made experimentally at several testing stations, including those at Brooklyn, Urbana and elsewhere. A critical analysis of the results indicates that in most cases definite conclusions regarding effect of depth are hardly warranted, since other factors, such as weight and character of solids introduced and time of digestion and withdrawal of sludge, have not been identical in the tanks under investigation.

With the rapid increase in recent years in the number of heated separate-digestion tanks, the need for more data concerning moisture content of sludge is even more critical. Mr. Kivell states in this issue (p. 62) that "the moisture content of sludge (in heated separate tanks) seems to depend mostly on the character of raw sludge being digested. Water depth of the digestion tank has very little, if any, effect on the concentration of sludge. Analyses of the sludge in a number of tanks at one-foot intervals indicate a slight compression due to depth of sludge. This increase in solids content will run from 0.5 to 1.0 per cent."

Dr. Rudolfs states (p. 75) that "the concentration of the final sludge depends upon the density of the initial sludge and upon the time of storage. The height of the liquid or sludge column had no effect upon the density of the sludge, nor upon the rate of concentration." In these studies sludge depths of 3, 6 and 9 feet were compared.

The increasing popularity of combined digestion of settled and activated solids, as practised at Essen-Rellinghausen, Pomona, Charlotte, North Toronto, Springfield, Salem and Chicago West Side, indicates that we must have more analyses similar to those presented on p. 35, by Dr. Fischer, in connection with his investigations at the Salem plant.

A study is being made of the moisture content of sludge, among other subjects, by a committee of the American Society of Civil Engineers, under the chairmanship of Mr. Samuel A. Greeley. Data on the moisture content of sludge in digestion tanks would be of great value to this committee. The need for such data was discussed by the writer in *Civil Engineering* for November, 1930 (p. 97).

It would greatly aid the progress of sludge digestion if the operators of digestion tanks would include, as routine procedure, analyses of sludge at various depths in the digestion tanks, analyses of fresh solids and sludge

withdrawn and determination of temperatures in digestion tanks by means of recording thermometers.

The determination of volatile or organic solids in sludge should also be critically examined. Any sewage chemist knows that a varying proportion of what is frequently referred to as organic matter is actually carbon dioxide or water present in inorganic compounds. That is why results are reported as volatile, rather than organic, matter.

When some of these gaps in our knowledge are filled with precise information we will have more confidence in the basic assumptions for the design of digestion tanks than we now have.

CORRECTION

In the article in the October, 1930, issue of THIS JOURNAL by W. D. Hatfield and Kenneth H. Morkert, entitled "Notes on the Determination of Biochemical Oxygen Demand," page 525,

$NaCl$	58.5	grams per liter
$MgSO_4$	60.2	grams per liter
$CaCO_3$	103.0	grams per liter

should read

$NaCl$	0.03	gram per liter
$MgSO_4$	0.06	gram per liter
$CaCO_3$	0.10	gram per liter

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North Carolina Sewage Works Association Eighth Annual Meeting

Hendersonville, North Carolina

October 13–15, 1930

The Eighth Annual Meeting of the North Carolina Sewage Works Association was held in conjunction with the Tenth Annual Meeting of the North Carolina Section of the American Water Works Association, at the Skyland Hotel, Hendersonville, October 13, 14 and 15, 1930. Sixteen states of the South, East and Middle West, and one foreign country were represented at the meeting. The registration reached 236, of whom 131 were city officials, superintendents, plant operators, engineers and public health officials actively engaged in the planning, design, construction, operation and financing of water and sewage works; sixty-one were commercial representatives of manufacturers and dealers in water works and sewerage equipment and supplies; nine were special representatives of professional journals and the press; and thirty-five were ladies and other visitors. The exhibits of about thirty firms were attractively arranged in the lobby and adjoining rooms of the hotel, and, as usual, constituted one of the most attractive features of the convention.

President C. W. Smedberg of Greensboro and Vice-President T. C. Patterson of Mount Holly presided at the sessions of both organizations.

The opening morning of the convention was devoted to registration, a general get-together for conversation, renewal of old acquaintances and the establishment of new ones and for the inspection of manufacturers' exhibits.

The afternoon session of the first day was devoted to papers on water supply.

The City of Hendersonville was host to the convention, Monday evening, at a dinner at Hotel Skyland, which was enjoyed by more than 200 guests. Hon. W. M. Sherard, Mayor, welcomed the visitors in a very pleasing address, and commended them for the splendid professional service which they are rendering the municipalities and industries of the State. President Smedberg responded for the Association, thanking the city officials for their kind hospitality and tireless effort which had made the meeting so pleasant. Mr. J. H. Lampley, Manager of the Board of Water Commissioners, presented a paper giving the historical background and description of the development of the splendid and abundant mountain water supply of the City of Hendersonville. Following the dinner, the annual Association ball was enjoyed by a hundred couples from ten until two o'clock.

Mr. Geo. F. Catlett of the North Carolina State Board of Health opened the program Tuesday morning with a paper "Sewage Flows," in which he showed graphically the hourly, daily and seasonal variations in sewage flows for a large number of North Carolina municipalities in which accurate and long-time records have been obtained by gauging. Characteristic curves for different types of communities have been established, and the effects of industrial waste discharge and infiltration demonstrated. Mr. Michael J. Blew, Research Engineer of the Dept. of Public Works, Philadelphia, Pa., followed with a paper on "Chemical Contamination of Public Water Supplies and Its Effect upon Health," in which he advanced the suggestion that dissolved materials resulting from the discharge of sewage and industrial wastes into streams used as sources of water supply may constitute a serious menace to health, that the physiological effects of such dissolved matter should be investigated and that chemical, as well as bacteriological, standards should be established for determining the safety of water supplies for domestic consumption. A very interesting paper entitled "The Separation, Treatment and Disposal of Sewage Solids" was given by Mr. John R. Downes, Supervising Engineer of the Plainfield, N. J., Sewage Treatment Works. Mr. Chas. C. Hommon, Sanitary Engineer, United States Public Health Service, Canton, Ohio, read a paper on "Utilization of Imhoff Tank Sludge for Farm Fertilizer," describing the successful method employed at this plant of pumping digested sludge directly from the tanks to farm land in the vicinity of the treatment works.

The session was concluded by a lively round-table discussion, led by Mr. E. G. McConnell, Supt. of Plants, Charlotte, N. C., on general sewage treatment topics. Among the subjects discussed were: Advantages of agitation of sludge during digestion, the relative importance of drainage

and evaporation in sludge drying, proper concentrations and depths of sludge to be drawn on drying beds, the processing of digested and dried sludge for use as commercial fertilizer, and forecasts as to the ultimate type of sewage treatment.

The papers presented Tuesday afternoon were on water supply topics.

The tenth annual Association banquet was held Tuesday evening. Entertainment in the form of singing, dancing and instrumental music was furnished by local talent. Mr. Stanley H. Wright, City Engineer of Asheville, presided as toastmaster in his best English manner. Mr. E. G. McConnell gave an interesting history of the ten years development of the North Carolina Section.

The Wednesday morning program was opened by Mr. Roy S. Lanphear, supervising chemist of the Worcester, Mass., Sewage Treatment Works, with a paper, "The Treatment of Sewage Containing Industrial Wastes," giving his experience in dealing with the complicated problems at Worcester. Mr. R. V. Toms, Supt. Water and Sewer Depts., Shelby, N. C., described the methods which he employed in starting a new Imhoff tank in operation. "Activated Sludge Digestion at Salem, Ohio," was the subject of a paper by Dr. Anthony J. Fischer of the Dorr Co., New York, in which he described his extensive research studies on the digestion of activated sludge. Dr. F. W. Mohlman, Chief Chemist of the Sanitary District of Chicago, forwarded slides illustrating the various sewage treatment plants of the Sanitary District. The slides were presented by Mr. H. G. Baity. Mr. Geo. F. Catlett of the North Carolina State Board of Health gave the final paper of the meeting on "The Industrial Waste Problem in North Carolina," in which he discussed the stream pollution problems with which the industries are faced, the extensive studies and investigations which have already been made by the industries and state agencies and the program for the future.

At the joint business meeting of the two associations Greensboro was selected as the next convention city, and the dates fixed as November 2, 3 and 4, 1931. The officers elected for the coming year are as follows:

President, A. S. Lyon, Rocky Mount, N. C.; *Vice-President*, Geo. S. Moore, Albermarle, N. C.; *Secretary-Treasurer*, H. G. Baity, Chapel Hill, N. C.; *Editor*, E. G. McConnell, Charlotte, N. C.; *Representatives on Board of Control, Federation of Sewage Works Associations*, H. E. Miller, Raleigh, N. C., W. M. Piatt, Durham, N. C.; *Chairman of Nominating Committee*, J. O. Craig, Salisbury, N. C.

The Section authorized the appointment of a special committee to represent it before the 1931 General Assembly in support of ample appropriation for the very necessary work of stream gauging.

H. G. BAITY, *Secretary*

New England Sewage Works Association Second Fall Meeting

Fitchburg, Massachusetts

October 15, 1930

The Second Fall meeting of the New England Sewage Works Association was held at the Hotel Raymond, Fitchburg, Mass., Wednesday, October 15, 1930.

In spite of the inclement weather forty-five members and guests attended the various sessions.

The meeting was called to order by President Coburn at 10:30 A. M. Mr. Coburn introduced the Hon. Joseph N. Carriere, Mayor of Fitchburg, who welcomed the Association to the city.

The first paper of the morning session, entitled "Screenings," was presented by Mr. Frank L. Flood of Boston and was followed by general discussion from the floor.

The second paper, "Importance of Cost Keeping for Successful Sewage Treatment Plant Operation," was presented by Mr. Philip L. Taylor, and also was followed by a general discussion.

"Sludge Disposal," the third paper, was presented by Mr. Frank H. Kennedy, City Chemist of Brockton. This paper was likewise thrown open to general discussion.

Mr. Herbert B. Allen, Chemist of the Fitchburg Sewage Treatment Plant, gave a brief description of the plant and its history. He also distributed to the members a pamphlet giving the details of construction and operation of the treatment works.

The President introduced Mr. Warren J. Scott, Chairman of the Committee on Sewage Plant Records, who gave a brief review of the Committee's report which was completed and ready for action by the Association. The Association voted to accept the report with thanks for the Committee's very valuable work.

It was voted that the Executive Committee be instructed to inquire into the feasibility of having this report printed for distribution.

The morning session adjourned at 1 P. M. Luncheon followed immediately at the Hotel Raymond.

Directly after luncheon the members proceeded by automobile to the sewage treatment plant. On arrival at the plant, Mr. Pierce, Commissioner of Public Works of Fitchburg, and Mr. Allen acted as guides, explaining the operation of the plant. The heavy rain interfered with the enjoyment of the inspection trip and necessitated an early return to the hotel.

During the period of waiting for the dinner hour the members enjoyed

an impromptu miniature golf tournament held on the indoor links of the Hotel Raymond, under the leadership of Mr. Philip W. Taylor.

Dinner was held at the Hotel Raymond at 6:00 P. M. After the dinner a round-table, discussion was held on the following subjects:

1. Garage Wastes, discussion opened by Mr. Edward Wright.
2. Methods of Collection and Preservation of Samples, opened by Mr. William Rogers Copeland.
3. Mechanical Equipment for Treatment Plants, opened by Mr. Frank L. Flood.
4. Methods of Handling Scum and Measuring Sludge, opened by Mr. Warren J. Scott.

General discussion, participated in by a number of the members, followed each of these topics, the round-table discussion proving of great interest to all.

The meeting adjourned at 9:00 P. M.

F. W. GILCREAS, *Secretary*

Missouri Water and Sewerage Conference
Sixth Annual Meeting

Columbia, Missouri

October 23–25, 1930

The design and operation of municipal waterworks and sewerage systems were taken up in detail at the Sixth Annual Meeting of the Missouri Water and Sewerage Conference held in Columbia, October 23, 24 and 25, 1930. Many interesting papers were read and discussed during the meeting, which were of value to those present. The registration was larger than ever before, 92 persons having registered before the close of the meeting.

The following speakers from out of the state added to the success of the meeting: J. R. Baylis of Chicago, A. E. Gorman of Newark, N. J., L. H. Enslow of New York and H. B. Crane of Chicago. The other speakers were Missouri men well known in the waterworks or sewage-treatment field. The conference is particularly indebted to Dean McCaustland of the College of Engineering, University of Missouri, and his faculty who gave valuable assistance on the program.

The conference members were served a luncheon at the Columbia City Water and Light Plant by the City of Columbia, following an inspection of the plant on Thursday, October 23.

The annual banquet was held on the evening of October 24. Dr. James Stewart, State Health Commissioner, was the toastmaster. Doctor

Allen, Dean of the Medical School of the University of Missouri, gave a very interesting talk on the evolution of the heart. Other speakers were H. A. Buehler, State Geologist, E. J. McCaustland, Dean of the College of Engineering, University of Missouri, and Hon. W. J. Hetzler, Mayor of Columbia. Music for the dinner was furnished by the School of Fine Arts of the University of Missouri. Following the after-dinner talks, much hilarity was occasioned by J. A. Strang's "Rogues' Gallery."

The papers on sewage topics were as follows: "Sewage Pumping Stations," by C. K. Matthews of the Burns and McDonnell Engineering Company, Kansas City; discussion by E. S. Glenn, City Engineer, Carthage: "Causes and Prevention of Foaming in Imhoff Tanks," by George S. Russell, Russell and Axon Engineering Company, Saint Louis; and discussion by William Lehr, Superintendent of Water Works and Sewers, Eldon: "The Activated Sludge Process in Small Installations," by F. M. Veatch, Black and Veatch Engineering Company, Kansas City; discussion by Hugh Brown, Superintendent of Water and Sewage Works, Vandalia: "Requirements of Successful Sewage Treatment Plant Operation," H. M. Bosch and H. D. Peters, Asst. Public Health Engineers, State Board of Health of Missouri.

Following the reading of papers Saturday morning, a short business session was held before adjournment. Those present at this meeting were in favor of continuing to hold the annual meeting of the conference in different cities as in the past in preference to locating permanently in one city. Also, the annual water and sewage operators' school held under the auspices of the State Board of Health and the Engineering School of the University of Missouri was highly commended and all were in favor of continuing this yearly school.

The following officers were elected for the coming year: Chairman, J. N. Wells, Supt. Joplin Water Works, Joplin; Vice-Chairman, E. E. Wolfe, City Chemist, Hannibal; Secretary-Treasurer, H. D. Peters, Assistant Public Health Engineer, State Board of Health, Jefferson City.

Executive Committee: R. L. Barker, Supt. Water Works, Odessa; O. L. Hebbler, Supt. Water Works, Higginsville; Hugh Brown, Supt. Water Works, Vandalia; Wm. J. Gray, Supt. Springfield City Water Company, Springfield.

H. D. PETERS, *Secretary*

Iowa Conference on Sewage Treatment
Twelfth Annual Conference

and

Iowa Wastes Disposal Conference
Fourth Annual Meeting

Ames, Iowa

November 13–15, 1930

The Twelfth Iowa Sewage Treatment Conference and Fourth Iowa Wastes Disposal Conference was held at the Iowa State College, Ames, November 13, 14 and 15, 1930. Sixty sewage treatment plant operators, engineers, municipal officials and representatives of creameries, canneries and packing plants attended the sessions, in addition to classes of college students.

The fundamentals of sewage treatment were presented mostly as lectures by authorities in this field, both from the college and from outside. Motion pictures and small models of plants were used to make this material clear and interesting. Problems of plant operation were handled through several round tables in which the entire group participated; these were especially valuable in the exchange of practical experience on the many different problems confronting plant operators. A laboratory in which plant control tests were made proved both interesting and instructive. The sessions on the treatment of industrial wastes were devoted to an explanation of the principles involved and to a round-table discussion of problems in handling creamery wastes, packing plant wastes and cannery wastes.

The conference of 1930 has been significant in two ways. First, the large attendance of municipal plant operators shows an awakened interest among the municipalities of the state in securing successful and intelligent operation of their sewage treatment plants. Second, the presence of representatives from creameries, canneries and packing plants of the state showed that these industries are becoming aware of their responsibility in treating their waste products in a manner that will leave them inoffensive and harmless when discharged into an outfall sewer or watercourse.

Topics presented on the program were as follows:

"The Trend in Sewage Treatment," L. F. Warrick, State Sanitary Engineer, Wisconsin State Board of Health, Madison.

"Sewage Tanks and How They Work," Earle L. Waterman, Prof. Sanitary Engineering, University of Iowa, Iowa City.

"The Purpose and Use of Sewage Filters," Clifford Lewelleyn, Engineer, H. R. Green Co., Cedar Rapids.

"Separate Sludge Digestion *vs.* Imhoff Tank Digestion," C. H. Currie, President, Currie Engineering Co., Webster City; A. H. Wieters, Chief Engineer, State Dept. of Health, Des Moines.

"Algae as Indicators of Sewage Pollution," Wm. P. Mark, Jr., Assistant Sanitary Engineer, State Dept. of Health, Des Moines.

"Collecting Significant Data on the Character of Flow of Sewage," Perry LaRue, Civil Engineer, Dept. Bldg. and Grounds, Iowa State College.

"Round Table Discussion on Sewage Treatment Plant Operators' Problems," Chairman: C. H. Currie, President, Currie Engineering Co., Webster City.

"What Is a Good Sewage Plant Effluent?" Ernest Boyce, Chief Engineer, Kansas State Board of Health, Lawrence.

"The Chemistry and Sanitary Science of Sewage Treatment," Jack J. Hinman, Jr., Chief Water Lab. Div., State Hygienic Laboratories, Iowa City.

"Practical Plant Control Tests," in charge of Sanitary Engineerng Division, State Department of Health and Bacteriology, Iowa State College.

"The Sewage Assimilating Power of a Stream," W. E. Galligan, Assistant Professor in Charge of Sanitary Engineering, Civil Engineering Department, Iowa State College.

"The Effects of Industrial Wastes on the Operation of Municipal Sewage Treatment Plants," L. F. Warrick, State Sanitary Engineer, Wisconsin State Board of Health, Madison.

"Round Table Discussion on Industrial Waste Treatment," Chairman: A. H. Wieters, Chief Engineer, State Department of Health, Des Moines.

The annual banquet and meeting of the Iowa Wastes Disposal Association was held Thursday evening, November 13, at the Iowa State Memorial Union. Jack J. Hinman, Jr., President of the Association, presided at the meeting which followed the banquet and entertainment. An explanation of the organization and purpose of the Association was given by Mr. Hinman for the benefit of the new members.

The secretary then read the minutes of the last meeting; by motion they were approved. A financial report of the business of the Association was given by the treasurer.

The president called for a report by the Legislative Committee. The secretary read a letter from Mr. Howard Green, Chairman, setting forth the work of the committee during the past year. This included the preparation of a Sanitary District Act, really a revision of the one suggested to the 43 General Assembly, which meets certain objections advanced by the Legislature. A second bill is being prepared which pro-

vides a Sanitary Commission empowered to act on matters of stream pollution. Work is being carried ahead on the Sewer Rental Law proposed at the meeting of this association a year ago. Mr. A. H. Wieters followed the letter setting forth the progress of the committee, with a further explanation of the legislation contemplated. Upon motion by Wieters, seconded by Mr. Bufkin, the committee was re-appointed and instructed to continue its efforts on vital legislation affecting sanitary matters.

At the close of the discussion of new business the election of officers for the ensuing year was held. Nominations were called for and ballots taken. The count showed all officers re-elected for 1931. They are as follows: *President*, Jack J. Hinman, Jr., Iowa City; *Vice-President*, A. H. Wieters, Des Moines; *Directors*, Bert Stull, Storm Lake, and Howard R. Green, Cedar Rapids; *Representatives to Board of Control, Federation Sewage Works Associations*, Max Levine, Ames, and Earle L. Waterman, Iowa City.

LINDON J. MURPHY, *Secretary-Treasurer*

Reviews and Abstracts

H. W. STREETER

Gas Formation from Imhoff Tank Scum

By Dr. H. Bach

Gesundheits-Ingenieur, **53**, 790 (Dec. 6, 1930)

Abstracted by G. P. Edwards

Scum which often forms on digestion tanks causes considerable trouble in operation not only because it occupies a large space but also because it reduces the size of the gas outlet and therefore the yield of gas. In Imhoff tanks the scum may interfere with settling action by entering the settling chamber.

Scum may be removed either by skimming it from the top or by mixing it with the bottom sludge. In skimming, the scum is removed undigested and the gas yield is reduced. It is more desirable, therefore, to mix the scum with the settled sludge, if it can be done economically without disturbing the digestion process. Usually scum is more easily mixed with the settled sludge in a separate digestion tank than in a two-story tank. When mechanical mixing of the scum with the bottom sludge seems feasible, the scum may be held under the surface of the liquid by porous covers of wood or spongy concrete. In this way, clogging of the gas collection apparatus is prevented.

In order to determine to what degree scum will digest and whether it will interfere with normal sludge digestion, scum samples were collected from four different Imhoff tanks, Essen-Nord, Essen-Frohnhausen, Essen-Nord-West and Oberhausen. In each case several sections of scum from top to bottom were taken from each tank and composited. From this composite an average sample was obtained. Each of the four samples was analyzed as soon as possible. Exactly 100 grams of each scum sample and 400 grams of distilled water were placed in litre flasks fitted with gas collection apparatus. The samples were set up in duplicate at room temperature, which varied from 20.0° C. to 26.5° C., averaging 22.5° C. Once daily the flasks were shaken gently. Gas from the various samples contained on the average from 65.3 to 71.5 per cent methane. The digestion was considered complete when no appreciable amount of gas was formed for a week. Table I shows a comparison of the composition of the initial and final scum. The results show that scum is easily

digested by anaerobic organisms and that the gas formed is similar to that from a sludge digestion tank.

TABLE I

COMPOSITION OF SCUM BEFORE AND AFTER DIGESTION

	Essen-Nord		Essen-Frohnhausen		Essen-Nord-West		Oberhausen	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Total solids (gm.)	20.4	17.16	17.8	11.5	25.4	20.65	20.3	14.1
Per cent decrease		15.7		35.4		18.5		30.6
Organic solids (gm.)	13.87	10.79	12.71	6.36	18.31	13.97	14.76	8.94
Per cent decrease		22.2		50.0		23.7		39.5
Grease (gm.)	4.92	3.16	3.31	0.77	5.72	3.99	3.25	1.26
Per cent decrease		35.9		76.8		30.2		61.5
Nitrogen (gm.)	0.398	0.386	0.498	0.288	0.457	0.372	0.548	0.374
Per cent decrease		3.02		42.2		18.6		31.8
Sulphide sulphur	0.153	0.231	0.039	0.053	0.107	0.248	0.131	0.233
Per cent increase		51		36		132		78
Heat value from scum (B. t. u.)	410	287	338	145	565	407	402	224
Heat value from gas (B. t. u.)		83		277		167		142
Heat value from scum and gas (B. t. u.)		370		422		574		366
pH	6.9		6.0		6.5		6.3	

TABLE II

GAS PRODUCTION FROM SCUM

	Essen-Nord Cc. Gas	Essen-Frohnhausen Cc. Gas	Essen-Nord-West Cc. Gas	Oberhausen Cc. Gas
Per gram–total solids	117	389	170	186
Per gram–organic solids	171	545	236	256
Per gram–digested organic solids	771	1090	997	649

The amounts of gas calculated from 1 gram of total or organic solids is shown in Table II. In the case of Essen-Frohnhausen, the yield was considerably higher than is generally obtained from fresh solids. From the other three plants, an average quantity was obtained. It may be concluded that the digestion of scum will increase the gas yield, especially in treatment plants such as Essen-Frohnhausen, which receives only

domestic sewage. It is interesting to note that only part of the organic matter disappearing during digestion was gasified. Physically, the digested scum was similar to normally digested fresh solids. Chemically, of course, the digested scum is different because of its high content of oil and grease. Whether this will interfere with the use of digested scum as fertilizer will depend on the proportion of scum to settled solids. The increase in sulphides during digestion is due to the reduction of sulphates.

Scum from the Essen-Frohnhausen plant, which treats only domestic sewage, digested the best. The scum from the Essen-Nord and the Essen-Nord-West plants, which contained difficultly digestible mineral oil and grease, digested poorly.

Heat values of the scum before digestion and of the scum and gases after digestion were about the same, indicating that there is no appreciable amount of self-heating.

Removal of the heavy scum from the digestion tank of the Munich treatment plant decreased the gas yield considerably. Since the Munich sewage is essentially domestic, the heavy scum was composed of easily-digested organic matter similar to that from the Essen-Frohnhausen plant. A scum layer several meters thick such as was found in Munich is formed when the layer of floating solids dries and digestion stops. More solids accumulate and the scum layer gradually becomes thicker and thicker. It is evident that the digestion of scum with settled sludge will result in a higher gas yield. The method of digesting the scum depends upon local conditions.

Sewage Research at Manchester

Annual Report of the Rivers Department, City of Manchester

For the Year Ending March 26, 1930

BY EDWARD ARDERN

ABSTRACTED BY F. W. MOHLMAN

Dr. Ardern's annual reports always include, as appendices, a summary of the results of research carried on since the last report. The 1930 volume has four appendices, as follows:

1. The methylene blue stability test has been investigated with regard to its value as an index of the quality of activated-sludge and contact-bed effluents from the Withington and Davyhulme Works. Samples of the effluents were incubated at 18–19° C. in 4-ounce bottles, to which had been added 1 cc. of 0.1% solution of methylene blue.

The Davyhulme contact-bed samples (28), containing an average of 8.1 p. p. m. nitrate nitrogen, and with a 5-day B. O. D. of 30.0 p. p. m., decolorized in $4^1/_2+$ days. The Davyhulme activated sludge samples (16), containing 1.0 p. p. m. nitrate nitrogen, and with a 5-day B. O. D. of 15.9 p. p. m., also stood up for an average of more than $4^1/_2$ days.

The Withington activated-sludge samples (306) decolorized in 3 days or less in 32 samples, while 40 more decolorized up until the 5th day, and the remaining 234 stood up more than 5 days.

Decolorization in less than 3 days indicates that the effluent is of doubtful character. The results of the stability test seem to correlate with the results of the Scudder test for putrescibility (3-minute oxygen absorption from permanganate, before and after incubation at 27° C. for 5 days), but not with the stability based on the B. O. D. The addition of 10 p. p. m. nitrogen as nitrate to a sample which decolorized in 1 day increased the time to 3 or 4 days.

(*Abstractor's Note:* The A. P. H. A. Standard Method now specifies 0.4 cc. of 0.05% methylene blue in a 150-cc. bottle, while in the Manchester tests 1.0 cc. of 0.1% solution was used in a 4-ounce bottle. The former concentration is 1.3 p. p. m. and the latter 9.0 p. p. m. The concentration now recommended by the A. P. H. A. has been reduced below that formerly recommended because it was found that higher concentrations had an inhibitory effect on bacteria and prolonged the period before decolorization occurred, thus indicating a sample of higher stability than would be indicated by a comparison of oxygen resources (dissolved oxygen plus nitrate oxygen) and oxygen demand. With lower concentration of methylene blue it is probable that the Manchester tests would have decolorized more rapidly and in closer correlation with the true stability.)

2. The effect of chlorine on the oxygen demand of combined activated sludge plus contact-bed effluents was studied by adding various amounts of sodium hypochlorite to samples in the laboratory. The average results of four tests were:

Chlorine P. p. m.	5-Day B. O. D. P. p. m.
0	30.9
1	26.1
2	20.7
3	14.9

In 9 further tests, with addition of 2.8 p. p. m., and 0.5 p. p. m. residual, the results gave a B. O. D. of 37.6 p. p. m. before chlorination and 17.3 p. p. m. after chlorination, or an apparent reduction of 54 per cent. In the absence of proof of the permanency of the effect of chlorine, judgment must be reserved regarding the effect of such treatment on an unsatisfactory effluent before disposal in a stream, although there is no reason to sup-

pose that it would prove any more harmful (than an unchlorinated effluent with the same B. O. D.) when discharged into a rapidly flowing stream affording a relatively high dilution.

Further laboratory studies were made of the effect of pre-chlorination of raw sewage. Conclusions recommend the use of chlorine for odor destruction or for highly septic sewage.

The effect on the activated sludge process of addition of 6.0 p. p. m. chlorine to the pre-settled sewage was investigated in the laboratory. No great harm was done by the chlorination, although there was evidence of the partial disintegration of the flocs of the sludge in contact with chlorinated sewage, and with 12 p. p. m. chlorine turbid effluents were produced.

Digestion experiments with solids from chlorinated sewage showed a lag period of 6 days before gas production started, but a rapid initial production of gas when the chlorinated solids were set aside for 15 days in the laboratory. The temperature of digestion was 37° C.

3. Extensive laboratory studies were made of digestion of sewage solids at 60°, 80°, 100°, 120°, 140° and 160° F. in Erlenmeyer flasks. The sludge mixtures consisted of two parts of ripe digested sludge to one of fresh settled sludge and one of activated sludge. The tests at 140° and 160° F. produced no gas after the second day and were discarded. The other tests were carried out to 40 days. At 80° F. as much gas was produced in 9 days as in 40 days at 120° F. A second portion of sludge was added, and in this case the rate at 120° F. increased, although still not so rapidly as at 80° F. It was concluded that the nature of the sludge was responsible for these unsatisfactory results, since it contained solids from industrial wastes. Solids from purely domestic sewage were then digested, and in this case it was found that 485 cc. of gas were evolved per gram of added volatile matter in 13 days at 80° F., while at 130° F. a rate of 470 cc. per gram was reached in 6 days, and after the addition of a further portion of sludge 516 cc. per gram in the following 6 days. It was concluded that a slightly more rapid rate of digestion could be obtained at 130° F. than at 80° F., with a sludge from purely domestic sewage. Further tests are to be made with quite fresh settled solids.

A reduction of 30 per cent of the organic matter was obtained at 80° F. The grease was reduced from 7.09 to 3.75 per cent, and the nitrogen from 3.3 to 2.66 per cent. Further tests indicated that the loss of nitrogen from activated sludge was greater than from settled solids, averaging 28.5 per cent for activated and 20.5 per cent for settled sludge.

Further tests of thermophilic digestion were made, with daily additions over a period of 20 days. Results indicated that a larger proportion of ripe sludge was necessary at 130° F. than at 80° F.

Tests in tin-plate containers holding 2000 cc. again indicated some in-

hibitory influence in Davyhulme sludge, likewise a low production of gas both at 130° and 80° F. The volume was not greatly different at the two temperatures. The settled sludge used in these tests was from 2 to 4 months old, which may partly explain the low gas yields.

Based on these tests digestion at 130° F. was indicated to be slightly more rapid than at 80° F. with solids from purely domestic sewage, but vice versa with Davyhulme solids.

4. Pot-culture tests were made of the relative fertilizing value of fresh and digested sludges. Italian rye grass, oats, and wheat were sown. The fresh sludge contained 2.33 per cent nitrogen and the digested 2.20 per cent. Equal weights of nitrogen (40 lb. per acre) were applied. The digested sludge gave greater yields of oats and wheat, but not of grass, than the fresh sludge. Higher yields were obtained in all cases with equal weights of nitrogen in ammonium sulphate. It is concluded that the sludges were of low fertilizer value, but that the digested sludge was the better of the two.

Twelfth Report (1930) of the Sewage Commission of the City of Moscow

BY S. N. STROGANOFF

ABSTRACTED BY H. GLADYS SWOPE FROM FRENCH RÉSUMÉ

A review of results of research studies over a period of twenty-five years is presented in a series of twenty-six papers.

The first paper, by S. N. Stroganoff, is an historical résumé of the entire work. The Commission was established in August, 1904, in order to study biological purification in the irrigation fields of Lublino. There are now five laboratories: at Lublino, Lubertzi, Kojoukhowo, Jegorievsk and Spasskaya. The experimental station at Lublino consists of sedimentation tanks, aeration tanks, percolating filters and contact beds (aerofilters). The one at Lubertzi includes sedimentation tanks, separate sludge-digestion tanks, tanks for the retting of hemp and sludge drying beds. At Jegorievsk there are sedimentation tanks, aeration tanks and aerofilters for the treatment of dye-house wastes. There are sedimentation tanks, a separate sludge-digestion tank and an aeration tank at Spasskaya for the treatment of night soil. The activated-sludge plant at Kojoukhowo is just being put in operation and comprises aeration tanks, aerofilters and lagoons.

Since 1917 all of the work has been under the direction of S. N. Stroganoff.

A résumé of the papers presented in commemoration of the twenty-fifth anniversary follows:

(1) "Changes in the pH Value of Sewage during Purification by Activated Sludge," by Miss N. A. Basiakine, Chemist. The author gives a complete chemical analysis of the Moscow sewage. Calcium and magnesium bicarbonates present in the sewage form $Ca(NO_3)_2$ upon nitrification of NH_4HCO_3, which gives a stable effluent. Very little change is noted in the pH, which remains at 7.8–7.7 unless the quantity of calcium and magnesium is not sufficient to form $Ca(NO_3)_2$. In this case NH_4NO_3 is formed which is oxidized to HNO_3 and the pH changes to 4.9. The addition of $NaHCO_3$ will carry the nitrification to completion. The changes noted in the pH value of a strong sewage during nitrification are probably due to a lack of bicarbonates.

(2) Miss Basiakine reports on "Determination of the Biochemical Oxygen Demand of Sewage Based on the Degree of Depletion of Oxygen during Aeration." The amount of oxygen absorbed during purification was calculated by determining the depletion of oxygen after various periods of aeration. The absorption of dissolved oxygen (Q) should be proportional to the depletion (d) and the time (t).

$$Q = Ktd$$

K was found to be proportional to the intensity of aeration (i), measured as the quantity of air in litres per minute, and was equal to $0.225i$ in this particular case.

(*Abstractor's Note:* The apparatus used and detailed report of this work will be found in the "Fifth Report of the Sanitation Department of the City of Moscow (Russia)," for 1925.)

Since the biochemical oxygen demand calculated by this equation was found to be four times greater than by the dilution method, the results were verified by oxidizing a solution of sodium sulphite, Na_2SO_3, by aeration. The oxidation of the sulphite was determined iodometrically.

The author believes that the B. O. D. determined by the "depletion" method (as she calls it) is correct, as it is a direct method, whereas the sewage has to be diluted using the dilution method, which may introduce errors. She has used the "depletion" method to determine the oxygen absorbed by activated sludge.

(3) A glass still head, with trap, is described by Miss Basiakine, for ammonia distillation.

(4) "Studies on the Treatment of Dye-house Wastes with Domestic Sewage from the City of Jegorievsk (Moscow)," by Miss W. A. Barache, Engineer. A description of the plant and results of some laboratory studies are presented. The plant comprises tanks for industrial wastes and night soil; a mixing tank for mixing 75 per cent industrial waste with 25 per cent sewage; a settling tank; four contact beds with arrangement for

aeration; aeration tanks (fill-and-draw-type); and an aeration tank of the Sheffield type using diffused air and no paddle wheels, but fitted with pumps for circulating the sewage.

The laboratory work comprised a study of the most efficient means of removing solids from the wastes. It was found that using 25 per cent night soil with 75 per cent dye-house waste was much more effective than dilution of the dye-house wastes.

(5) "Research Station at Lublino for the Study of Activated Sludge," by B. B. Besenoff, Engineer. Experimental work on activated sludge began at Moscow in 1915. There were two experimental plants built, one in 1917 and the other in 1919. In 1927 an experimental plant was built at Lublino. The plant consists of a preliminary settling tank in which 70 per cent of the suspended matter in the raw sewage is removed and an aeration tank for studying the flocculation of activated sludge, air being introduced by means of perforated pipes (diameter 1.3 inches), with openings 0.1 inch in diameter. The optimum amount of sludge is 8 to 10 per cent of the total volume. From 8.0 to 8.5 cu. ft. of air are required per cubic foot of tank capacity per hour. Reaeration tanks are provided, of the same construction as the aeration tanks, also final settling tanks, percolating aerofilters 13.1 ft. deep and ordinary percolating beds 6.5 ft. deep. Cinders (diameter $^1/_2$ to 1 inch) are used for filtering material. In the aerofilters the influent is applied through small wooden troughs, air being introduced under the false bottom of the troughs. In the other filters the influent is sprayed from nozzles.

The rate of treatment in the aerofilters was studied for 305 days during 1928–29. It was found that in applying the sewage at the rate of 8000 gallons per hour there was a 50 per cent reduction in the B. O. D. The air consumption was 18 cu. ft. per cu. ft. of waste treated. The detention period was 45 minutes.

A coagulated effluent could be applied to the filters in winter at the rate of 2 cu. ft. per cu. ft. of filter stone per day and in summer at a rate of 4 cu. ft. per day. With settling alone, the rate under winter conditions could not exceed 0.3 cu. ft. per day. The aerofilters could be dosed at the rate of 2.5 cu. ft. per day in winter.

(6) Prof. M. I. Bimanis, Professor of Engineering at the University of Riga, summarizes the experimental investigations which led up to the installation of the various sewage disposal works of the city of Moscow.

(7) "Operation of the Percolating Beds at the Krasnoe-Znamia Factory," by K. T. Warvaritcheff, Chemist. The total amount of oxygen which has been absorbed (in order to reduce the oxygen demand and for nitrification) during the passage of the settled sewage through the cinder beds can be calculated from the analysis of the raw sewage (after septic tank treatment) and the effluent from the percolating beds. This has been

expressed in grams of oxygen per cubic meter of filter bed and is called the "index of the oxidizing power."

(8) N. M. Welitchkine discusses "Studies on Evaporation in the Filtration Fields." The evaporation in the irrigation fields was determined theoretically by two formulae, that of Oldekof and of Penck. These were checked with the evaporation actually observed and the results were in good agreement during the summer months. Discrepancies in the fall were due to the difference in temperature between the air and sewage. An Assman psychrometer was used for observing the saturation deficit. During the summer evaporation can now be calculated directly by the use of the psychrometer.

(9) "Note on the Binary System of Drainage in the Intermittent Filtration Fields of Lubertzi," by M. M. Dworetzky, Engineer. A study was made of two types of drains, underground pipes and open surface drains. In the former case water is drawn to the pipes by capillary force and displaces the water body in contact with the drain pipes with no lowering of the water surface. In the latter case, the capillary effect is not produced and drainage is effected by gravitation only.

(10) A. T. Demine, Chemist, discusses "Seasonal Variations in the Composition of Moscow Sewage." Analyses showed an increase in concentration in winter and spring, the lowest results being in the summer and fall. These are shown in the following tabulation:

Parts Per Million

1925/26–1928/29 Seasons	Temp., °C.	Nitrogen Total	Nitrogen Ammonia	Oxygen Consumed	Chloride	Suspended Solids by Weight at 105°C.	Suspended Solids by Volume in Cc.	Total Solids, 105° C.	Bicarbonate Alkalinity	B. O. D., 5-day(?)
Summer	15.8	95.4	77.1	53.6	187	411	10.9	985	533	310
Autumn	13.0	109.2	95.1	61.2	209	489	12.5	1035	804	382
Winter	8.5	112.7	99.4	70.8	205	498	13.9	1075	645	430
Spring	8.5	118.9	99.5	75.5	218	538	13.1	1134	662	440
Yearly Average	11.5	109.1	92.8	65.3	205	484	12.6	1057	611	391

(11) "Experimental Plant for the Treatment of Night Soil," by B. I. Douroff, Chemist. The testing station included a grit chamber, settling tanks, a sludge-drying bed, a separate sludge-digestion tank and an aeration tank. It was designed to treat 5300 gallons of night soil per day.

(12) "A Few Organisms Indicative of Sewage Pollution," by N. G. Zakharoff, Biologist. The author studied the plankton found in the lagoons of the Lublino fields, in order to follow the stages of self-purification in the four sections through which the sewage passed. These four sections correspond to the ecological zones of Kolkwitz and Marsson's classification: polysaprobic, alpha- and beta-mesosaprobic. The following rare

organisms were found: *Hastatella radians* (Erlanger), *Actinobolus radians* (Stein) and *Craspedonotus vermicularis* (Stokes) classified as beta-mesosaprobic organisms, *Chlamydobotrys Korschikoffi* (Schkorb), an alpha mesosaprobic organism found in the first and second sections, and *Chlorochromatium aggregatum Lauterb*, a polysaprobic organism.

(13) "Work of the Commission for the Future Extension of the Moscow Sewerage System," by J. J. Zwiaguinsky, Chief Engineer of the Sanitation Department of Moscow. The city is divided into three sections: the first or central portion is only 7 sq. miles (8 per cent); the middle portion, 20 sq. miles (22 per cent); and the boundary portion, 64½ sq. miles (70 per cent). The daily average flow in 1933 will be approximately 84,000,000 gallons per day. By 1950 the sewers will increase to 491 miles with pumping stations and installations for the biological purification of domestic sewage and industrial wastes. The average daily sewage flow in 1950 will be 149,500,000 gallons, of which 26,000,000 gallons will be treated in the intermittent irrigation fields (8,000,000 gallons at Lublino and 18,000,000 at Lubertzi). Activated sludge treatment is recommended for 123,500,000 gallons. An experimental station for a daily flow of 3,250,000 gallons will be put in operation at Kojouchovo.

Water consumption in Moscow is now only 22.5 gallons per capita per day. The sewage is collected on the separate system and has a high organic matter content (the B. O. D. being nearly 500 p. p. m.). It contains considerable tannery and dye-house wastes.

(14) "Contributions of the Commission to the Work of Rural Sanitation," by I. A. Kertchiker, Engineer. The author presents an historical résumé of the first work on biological purification which was started in 1902 for the treatment of wastes from hospitals.

(15) "Determination of Dissolved Oxygen in the Presence of Activated Sludge," by K. T. Konstantinoff, Chemist. Activated sludge absorbs oxygen very rapidly, therefore, in order to determine the dissolved oxygen in various parts of the aeration tanks at different periods it is necessary to retard this absorption at the moment of sampling. It was found that this could be accomplished by the addition of a 5 per cent solution of mercuric chloride (0.10–0.15 cc. of $HgCl_2$ per 100 cc. of liquid and 1 per cent sludge, for a one-hour settling period). The $HgCl_2$ did not interfere with the determination of dissolved oxygen, when using the Rideal-Stewart modification of the Winkler method.

(16) K. N. Korolkoff, Chemist, discusses "Principles in the Construction of Aeration Tanks." He points out that there should be a rapid and effective mixing of the sewage and sludge; there should be no corners where sludge can deposit; and the diffusers for oxygen should be so placed as to have maximum efficiency. This latter point is very often overlooked.

(17) "Some Observations on Bacteriophage in the Purification of

Sewage," by T. S. Naguibine, Bacteriologist. A study was made of the bacteria found in the Moscow sewage ponds at 4° C. The average number of colonies per cc. found in raw sewage on Endo media during 1927–28 was 38,580,000; 1st pond, 2,510,000: 2nd, 182,000: 3rd, 33,000; and 4th, 7000. For the study of bacteriophage in sewage and effluents from ponds, lagoons, percolating beds and aerofilters, water was first filtered through paper and then through a Berkefield filter. From 0.02 to 1.00 cc. of this water was introduced into 10 cc. of a boullion culture of *B. Shiga* (40,000,000 per cc.), and incubated at 37° C. for 24 hours. Bacteriophage was found in the water at all stages of purification, the most being obtained in the effluent from the aerofilters. A study of the activity of bacteriophage according to the method of M. d'Herelle was not successful. A better method was to determine the minimum quantity required for lysis of the *B. Shiga* culture. Results with *B. coli* were less successful, apparently due to resistant strains present in the samples investigated. The bacteriolytic action was most pronounced during warm weather.

(18) "Night Soil Stations in the City of Moscow," by A. B. Nikitine, Engineer.

(19) "Study of the Retting of Hemp by the Digestion of Settled Sludge," by K. A. Owsiannikoff, Chemist. In the separate digestion of sludge from the clarification tanks, fatty acids are formed as intermediate products in the decomposition of the organic material. The pH of the sludge remains around 7.0–7.5, due to a considerable amount of bicarbonates and phosphates. These conditions are excellent for the retting of hemp. If the tank is heated to a temperature of 19.5° C. the retting takes place in 25 hours, whereas it ordinarily takes 8–10 days at 12° C.

(20) "Oxidizability Determined by the Dichromate Method," by E. S. Popoff, Chemist. A study was made comparing the method of Abbott (dichromate) with that of Kubel ($KMnO_4$ in acid solution) and the 5-day B. O. D. in order to determine the oxidizability of raw sewage. The oxidizability (dichromate method) expressed in terms of oxygen is 86.2 per cent of the B. O. D. and by the permanganate method is 24.5 per cent of the B. O. D. As a rapid method for determining the amount of oxidizable material in sewage the Abbott method was found to be fairly accurate.

(21) "Drying of Settled Sludge—A Laboratory Study," by N. M. Popoff, Chemist. A study was made of the optimum conditions for flocculation and filtration of settled sludge (fresh and digested), using the apparatus of Ostwald and Hahn (*Koll. Zeit.*, **30,** 62 (1922)). It was found that best flocculation was obtained with solutions of alum, $Al_2(SO_4)_3$, and ferric sulphate, $Fe_2(SO_4)_3$, at a pH of 5.0–5.5. Good results were obtained with sulphuric acid. The sludge should have a moisture content of 97.2–97.5 per cent. Filtration was increased 12–15 times after chemical treatment and 30 times by the use of vacuum. The temperature of the sludge also

affects filtration. After filtration the sludge contained 78–83 per cent moisture and in this condition could be shoveled, hauled away and used for fertilizer.

(22) "Industrial Wastes and Sanitation in Moscow," by B. M. Priyaloff, M.D. About 15 per cent (5,950,000 gallons) of the total sewage flow treated is industrial wastes. About 23,800,000 gallons of the industrial wastes flow directly to the Moscowa River. The flow is expected to reach 33,100,000 gallons, of which 90 per cent will be dye-house wastes. By 1933 this will be 40 per cent of the total flow estimated at 84,000,000 gallons per day.

(23) "Sedimentation Tanks at the Lubertzi Irrigation Fields," by K. T. Rasikoff, Engineer. Difficulties were encountered during purification on irrigation fields due to a very concentrated sewage. A study was made of the type of preliminary treatment to be adopted. Settling in Dortmund tanks, with separate sludge digestion, was found to be the most efficient scheme.

(24) "Agricultural Use of Sludge near the Lubertzi Fields," by P. S. Savostianoff, Agricultural Engineer. The sludge from the separate sludge-digestion tanks was used as fertilizer for growing potatoes. Its use as fertilizer is to be studied further.

(25) "The Rôle of Domestic Sewage in the Biological Purification of Dye-House Wastes," by W. M. Safronoff, Chemist. The treatment of dye-house wastes is very important for in certain villages and in some parts of the city of Moscow these wastes constitute 75 per cent of the total flow. Laboratory studies have been made concerning the treatment of these wastes. It was found that chemical precipitation did not produce a stable effluent. Biological purification (contact beds, activated sludge) could be used if wastes were diluted with 10–25 per cent domestic sewage. A colorless and stable effluent was obtained. As the dye-house wastes were almost sterile and without nitrogen or phosphorus, these elements were supplied by the domestic sewage.

(26) "Scientific Research Organizations in the Field of Sanitation in the Mining Regions of the Rhine and Westphalia," by V. E. Temonoff, Prof. and Dr. of Engineering at Leningrad. This is a review of the work in these districts.

The Effect of Sludge Circulation in Digestion Tanks on Gas Production, Sludge Capacity and Scum

BY DR. F. SIERP (RUHRVERBAND, ESSEN)

Gesundheits-Ingenieur, **53**, 810 (Dec. 13, 1930)

ABSTRACTED BY G. P. EDWARDS

Heating and pH control are two general methods for hastening sludge digestion. The effect of sludge circulation, however, is still being disputed. Recently it has been reported that due to sludge circulation the gas production is doubled, the digestion space requirements are halved and the scum problem is solved.

In 1907 during the operation of the first Imhoff tank, it was noticed that a thorough mixing of the fresh solids with the ripe sludge was most important. Even without a knowledge of the pH value and its influence on biological processes, it was recognized that the so-called acid digestion which takes place in fresh solids not thoroughly mixed with ripe sludge must be avoided. To promote more efficient digestion, fresh and old sludges have been mixed by different means to aid the natural mixing in the Imhoff tank.

In separate digestion tanks, rotation apparatus was used to imitate the natural mixing obtained in the Imhoff tank. Many types of circulation apparatus were used including Dorr-type equipment, pumps placed outside the tank, air lifts and pumps such as used by Prüss.

Bach and Sierp[1] investigated the value of sludge circulation, in 1921 and 1922. The following table shows results obtained at that time. In this experiment, fresh solids were added daily and a corresponding amount of water was withdrawn.

	Expt. 6, without Rotation	Expt. 7, with Rotation
Degree of mineralization	3.28	3.03
Proportion of mineral to organic solids—dry basis	1:0.87	1:0.79
Gas per gram dry solids	253 cc.	276 cc.
Gas per gram organic solids	341 cc.	394 cc.

Circulation caused an increased gas yield of 9.1 per cent on the basis of total solids and 13.4 per cent on the basis of organic solids. Fries has obtained an increase of 10–12 per cent in large-scale experiments at Essen-Rellinghausen.

In comparing the results from large treatment plants, the conditions at each plant must be examined critically. The fact that an Imhoff tank or a separate but quiet digestion tank yields only 0.28 cu. ft. per capita per day, whereas another with sludge rotation yields double that amount,

[1] Bach, *Gesundheits-Ingenieur*, **48**, Nos. 19 and 26 (1925).

means nothing. There are several Imhoff tanks which yield 0.53–0.70 cu. ft. per capita per day. In such a comparison, the temperature of the digestion tank, its size in relation to the included population, the amount of digestible industrial sludge and the organic solids added from storm water or activated sludge tanks must always be stated.

The small increase in gas production of 10–20 per cent does not warrant the cost of construction and operation of rotation apparatus, especially since all tests have shown that circulation increases the amount of worthless CO_2. This increase in CO_2 depends on the fact that CO_2 is much more soluble than CH_4 (1.019 CO_2 as compared with 0.037 CH_4 at 15° C.) and that this solubility increases proportionally with the pressure. Sludge lying at the bottom of a digestion tank 33 ft. deep will dissolve about twice as much gas as at the surface. During vertical rotation, the gas in the bottom

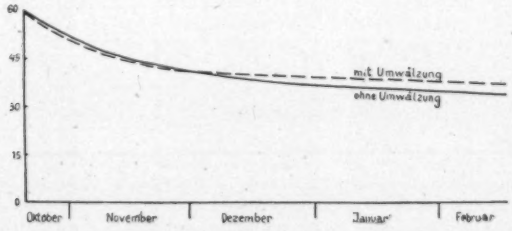


FIG. 1.

sludge expands and is liberated as it is brought to the top. This liberated gas is 96.3 per cent CO_2 and 3.7 per cent CH_4. Although the tanks in the Bach-Sierp experiment were only 1.25 ft. deep, the following differences in CO_2 content were obtained:

	Without Rotation (Per Cent)	With Rotation (Per Cent)
CO_2 content during the daily addition of sludge	8.2	12.2
CO_2 content after the daily sludge additions were stopped	23.7	24.2

Fries has found 25 per cent CO_2 in gas from sludge not rotated and 36 per cent from rotated sludge.

It is often maintained that sludge circulation causes a saving in construction cost and digestion tank capacity. Although 1.12 cu. ft. per capita is an average figure for digestion tank capacity for German conditions, there are many plants in Germany with the proper temperature and without rotation apparatus which operate satisfactorily with considerably less capacity. The Dorr digesters are not restricted to lower capacities, even

though equipped with sludge stirring apparatus, and Prüss[2] recommends 0.88 cu. ft. per capita, a saving of only 17.5 per cent. In a more recent article,[3] he is reported to have recommended 1.2 cu. ft. per capita with artificial heating to 80–90° F. Fries claims that in a quiet tank, the water content of the sludge, which is 82–90 per cent at the bottom and about 96 per cent at the surface, becomes equalized by sludge circulation so that it averages about 95 per cent throughout the entire tank, increasing the water content and increasing the space required.

The volume of sludge was measured daily for four months, in two digestion tanks about 5 ft. deep, one quiescent and the other with sludge rotation twice daily. As shown in Figure 1, the volume of sludge in the rotated tank was 3–5 per cent lower than in the quiet tank, for the first month. Later, however, the rotated sludge was considerably more bulky than the quiet sludge. In a deeper tank, the volume differences would be even greater.

Digestion capacity cannot be decreased below a necessary minimum to provide sufficient storage space during the winter months. Where winters are long, this storage space may be larger than the digestion space. For example, at Peoria, Illinois, the heated digestion tanks will provide 1.66 cu. ft. per capita digestion space and the unheated storage tanks, 2.12 cu. ft. per capita.

Stirring apparatus and flushing water have been used for decades in controlling scum in single-story and two-story digestion tanks. Both types of treatment have been satisfactory. It is doubtful whether screw pumps, which sprinkle sludge on the scum or draw the scum into the bottom sludge, are successful. The first plant equipped with screw pumps outside of the Ruhr Coal District has been in operation at Posneck for several months. A separate digestion tank of about 344,000-gallon capacity is equipped with three screw pumps requiring 7.5 h. p. each. The pumps are operated daily, a half-hour forward and a half-hour backward. Nevertheless, in about two months, a layer of scum 6.5 ft. thick has formed which must be removed by hand.

Conclusions

Regular or continuous rotation of sludge in a digestion tank increases the gas yield 10 to 20 per cent.

This increase in gas consists mainly of worthless CO_2.

The increased amount of gas does not compensate for the cost of rotation.

It has not been demonstrated that a digestion tank equipped with circulation apparatus requires less digestion space than a quiet one.

Stirring apparatus or a powerful stream of water is suitable for scum removal. The value of a screw pump is questionable.

[2] Prüss, *Gesundheits-Ingenieur*, **51**, No. 7 (1928).

[3] "Sewage Treatment and Disposal in Germany," *Surveyor*, **78**, 303 (Sept. 26, 1930).

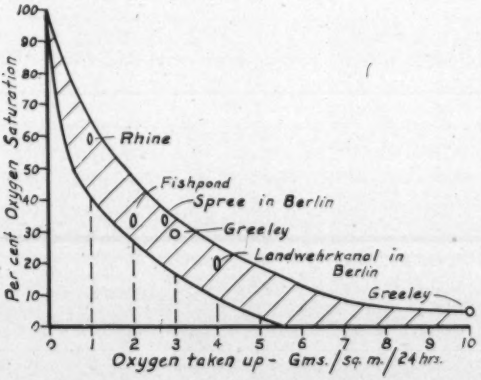
The River as Purification Works

BY DR. ING. MAHR, RUHRVERBAND, ESSEN

Surveyor, **78**, 618–19 (Dec. 19, 1930)

ABSTRACTED BY H. W. STREETER

Whether treated or not, all sewage eventually reaches a river. A river acts not merely as a carrier of sewage, but has natural agencies which finally restore the disturbed balance. In magnitude, the more important forces are those which break down organic refuse through the action of microscopic life; hence through biological action. When sewage is allowed to stand in contact with air, the putrefactive components are eventually reduced to mineral substances no longer putrescible. The amount of oxygen needed for complete reduction of sewage is known as its biochemical oxygen demand. In Germany normal sewage has a B. O. D. of 100–200 mg./litre (p. p. m.).



Similar processes take place in a river into which sewage is discharged. In that way the oxygen supply of the stream would soon be used up if the river did not replenish its normal supply of oxygen through diffusion at the surface and by assimilation from green aquatic plants. Tests and observations have shown at many places how great is this reaeration of a river under various conditions. The rate at which oxygen is taken up—as measured, say, in g./m.^{2} per day—is more vigorous the lower the temporary oxygen content has fallen—*i. e.*, the further the water is from saturation.

The diagram shows the average rates. The upper edge of the shaded

portion represents favorable and the lower line less favorable conditions.

With these data one can attempt to represent numerically the permissible burden of a river. It must be remembered that dissolved and undissolved substances in a river behave in different ways; the dissolved matter disperses itself over great distances, whereas the insoluble solids settle out and remain near the point where they enter the river. This leads to some such formula as the following:

$$Q = q.t\ (\frac{^1/_5 S}{a} + 60\ b)$$

Q = river water volume (m.³/sec.)
q = sewage volume spread over 24 hrs. (m.³/sec.)
t = mean river depth (m)
S = biochemical oxygen demand (total, first stage) of the filtered sewage (gm.s/m.³)
a = amount of reaeration of river (gms./m.²/day)
b = sludge content of the sewage (cm.³/litre, or l/m.³)

(The derivation of this formula has been given elsewhere—*Technisches Gemeindeblatt*, Aug. 5, 1930.)

The formula does not pretend to show exactly the quantity of sewage a stream may receive, but will show for average conditions how the various components of sewage burden the river and by what means the river may best be assisted in its work. A city of 50,000 population may serve as an example:

Sewage volume = 150 l. per head per day, from which q = 0.090 m.³/sec.; S = 150 g./m.³; a = 2 g./m.²/day.
Sludge volume = 1 l./head/day, from which b = 1/150 = 6.67 cm.³/l; t = 1 m.

When	b = 6.67	cm.³/l.	Q = 37	m.³/sec.
"	" = 1.0	"	" = 6.8	"
"	" = 0.4	"	" = 3.5	"
"	" = 0.2	"	" = 2.4	"

Thus, in the above case, dilution of about 25 times is needed with good mechanical clarification and about 400 times without clarification. The inflow of dissolved matter is much less important. If the first quantity in the brackets is doubled—representing practically the extreme case—the value of Q only increases 1.35 m.³/sec.

The suspended matter settles very quickly below the outfall point. It burdens the stream only for a short time, but intensely. The dissolved matter, on the other hand, continues in solution and travels with the water for great distances and times, while being slowly broken down. If there

are several pollution points on a river, the suspended matter may be deposited between one place and the next, and the river thus becomes practically clean again so far as insoluble matter is concerned. Dissolved matter, however, is little reduced after traveling some hours and is thus augmented by inflow from several sources of pollution.

Temperature plays an important part in the self-purification of a river. The breaking down of polluting matter and reaeration of the stream take place more slowly at lower temperatures.

Decomposition occurs more slowly in cold water. This can be a disadvantage when the polluting substances have to be broken down before a certain downstream point is reached. It can be an advantage if the self-purification distance is as long as may be desired.

In summer, rivers having sludge deposits must be watched, as clots of fermenting sludge may rise up and foul the river. These have a great oxygen-avidity. Admission of sludge to the river should therefore be reduced several months before the hot season.

Several practical conclusions are:

1. For big streams (from the formula, about 1000 times dilution) it is generally possible to dispense with purification works, removal of oil and coarser solids being sufficient.
2. Sludge should be introduced into a stream as far as possible from the bank.
3. If purification works have to be installed, the first essential is removal of sludge, with which a river is least able to deal.
4. Weirs in the river relieve the lower stretches of objectionable matter, by holding back sludge, but this beneficial action is lost if the amount of sludge becomes too great.

The more we understand stream self-purification, the better we can utilize the river as a part of our purification works. With wise and intelligent handling it will do valuable work, but it must be considered as a unit complete in itself.

Editor's Note—Abstracts of previous papers on stream pollution by Dr. Mahr were published in THIS JOURNAL, pp. 184–86, January, 1930, and pp. 642–43, October, 1930.

Los Angeles Successfully Reclaims Sewage for Replenishment of Underground Water Supplies

BY CARL WILSON

Western Construction News, pp. 473–4, Sept. 25, 1930

ABSTRACTED BY E. HURWITZ

Because of the rapid growth and development of Southern California and because the present water supply will not suffice for the ultimate needs of this area, it has become necessary to look forward toward conservation of the water supply. With this purpose in view the City of Los Angeles has had in operation since May 12, 1930, a sewage treatment plant designed and equipped to make a comprehensive study of the treatment of sewage with a view to reclaiming sewage for domestic or commercial use. The plant is of the activated-sludge type having a capacity of 200,000 g. p. d., with all appurtenances necessary to produce an effluent which can be turned back into the water supply or which may be stopped at any intermediate stage to produce an effluent applicable for different uses, for instance, irrigation of land or industrial and commercial use. The author gives a detailed outline of the items under investigation in their water reclamation studies. Notable among these items is the great amount of study allocated to the investigation of domestic and industrial wastes and their treatment and to the various methods of reclamation.

Sewage Reclamation Plant for Los Angeles

BY R. F. GOUDEY

Western Construction News, pp. 519–24, Oct. 25, 1930

ABSTRACTED BY E. HURWITZ

The Bureau of Water Works and Supply of Los Angeles has put in operation a complete sewage treatment plant to treat 200,000 g. p. d. The plant is designed and equipped for exhaustive research into every phase of sewage treatment. Essentially this plant is of the activated sludge type employing separate sludge digestion, with one-third the final effluent carried through complete treatment including coagulation, superchlorination, sedimentation, sand filtration and dechlorination with activated carbon. The plant is built to operate along standard lines of sewage treatment but is so designed that the various units can be easily altered to test schemes of treatment radically divergent from standard practice. All degrees of effluent from settled sewage to drinking water are produced.

The intake is a vertical diversion in a 48-inch sewer, which normally diverts one-quarter to one-third the entire flow to the plant. The sewage reaching the plant is strong, averaging during the canning season 530 p. p. m. suspended solids and 680 p. p. m. B. O. D.

Two clarifiers 20 ft. in diameter and 7 ft. deep equipped with Dorr mechanisms are provided. Each permits a two-hour detention period with normal flow and provides a surface rate of 635 gal. per sq. ft. per day. Provision is made for the adjustment of pH to the point of most efficient settling, 6.8, by addition of lime to the raw sewage. Low settling rates, pH control and efficient inlet and outlet details, make it possible to secure a removal of suspended solids averaging 82 per cent. Provision is also made for the addition of coagulants to secure further removal, if desired.

The aeration tanks, of which there are two, are 55 ft. long, 10 ft. wide and 10 ft. deep. They are equipped with paddles which revolve at 6.5 r. p. m. against air admitted from a single row of filtros plates. The amount of air added varies from 0.2 to 0.4 cu. ft. per gallon of sewage treated. The tanks are divided into compartments for use in various combinations. Aeration experiments point to multi-stage treatment as the most efficient under the conditions obtained at this plant. Other experiments are being conducted involving studies of sludge bulking; percentage of sludge return; treatment of sludge with chlorine, lime, and ferric chloride, to alter percentage volume of sludge in tanks; correlation of air used in reduction of B. O. D., power requirements, and maximum production of nitrates in the effluent.

Good results are obtained by the use of two clarifiers in series. The second clarifier acts as a chlorination detention basin and as a safety valve, intercepting any sludge which might escape the first clarifier. During the canning season the final effluent from the clarifier contained 2 p. p. m. suspended solids and 7.5 p. p. m. B. O. D.

One third of the final activated sludge effluent is further treated by coagulation with ferric chloride, mixture with returned ferric chloride sludge, superchlorination, sedimentation, filtration through sand and dechlorination with activated carbon. All wash water from the sand filter is returned to the aeration tank and any sludge which it may carry eventually reaches the digester. Practically 100 per cent removal of suspended solids is obtained in this manner. The effluent is further chlorinated with 25 pounds of chlorine per million gallons. The total contact period of chlorine and effluent through the clarifier and settling tank is about three hours. The chlorine residual never falls below 0.2 p. p. m. The effluent is then dechlorinated on a carbon filter and the final effluent is sparkling, clear, tasteless, odorless, colorless, free from suspended solids and turbidity, and has but a trace of B. O. D. and an

oxygen consumed value of 2.5 p. p. m. This effluent is returned to the water supply by disposal on spreading beds through which it is expected finally to reach the infiltration galleries, a mile-and-a-half below, from which part of the domestic water supply is obtained. Careful study is being made to learn the effect of this reclaimed water on the supply. Fourteen two-inch wells have been sunk in and around the beds for this purpose.

The sludge is dewatered in a decanter tank to about 20 per cent of its original volume and pumped to the digester. When necessary the pH is adjusted by addition of lime to the decanter tank. At present the digested sludge is dried on sand beds. Experiments are being made with mechanical filtration.

Operation costs based on costs obtained at this plant have been determined for a 25 m. g. d. activated sludge plant. Without filtration the cost figures $15 per m. g. and is distributed as follows: labor, $3.66; power, $1.65; chemicals, $2.50; depreciation, $3.21; research, $1.00: maintenance, $0.50: contingency, $2.04.

Reclamation of Treated Sewage

By R. F. GOUDEY

Western City, December, 1930

ABSTRACTED BY E. HURWITZ

The need and desirability of reclaiming the water from sewage is becoming increasingly greater in California. A plant to study methods of sewage reclamation has been put in operation in Los Angeles. This plant treats 200,000 g. p. d. and obtains an effluent that complies with the U. S. Treasury Department standards. The cost of producing this effluent is less than the cost of water brought in from outside sources.

The average of several hundred tests is shown in the table:

	Crude Sewage	Treated Sewage		Fully Treated	L. A. Water Aqueduct	Untreated Gallery
		Settled	Stabilized			
B. coli per cc.	100,000	50,000	1	0.00	0.05	0.00
Susp. solids	418	77	3.2	0.0	6.0	0.0
Turbidity	440	....	8.3	0.2	25	0
B. O. D.	515	222	9.1	0.99	1.25	1.0
Oxygen consumed	180	46	8.3	4.1	3.5	1.2
Organic N	48.1	37.3	5.08	2.25	1.3	0.5
Free NH_3	50	20	1.0	0.65	0.25	0.2
pH	6.8	6.6	7.0	7.1	7.3	7.2

The table demonstrates that the treated sewage is better than the aqueduct water and as good as gallery water.

British Methods of Dealing with River Pollution

BY H. MACLEAN WILSON

Municipal Sanitation, I, 672 (Dec., 1930)

ABSTRACTED BY DOROTHY W. HARDT

Official action in England in the direction of prevention of river pollution began (when the scandal of river pollution first forced itself into public notice) in 1866, with the appointment of investigating commissions. The most important step forward was taken in 1876 when the Rivers Pollution Prevention Act was passed, although this act did little good until the formation, in 1888, of County Councils and County Boroughs (and Joint Committees from these), for the purpose of controlling stream pollution. The appointment of a Royal Commission in 1898 resulted in a long report in 1915, on suitable methods of sewage treatment and extensive recommendations which gave promise of considerable relief. No consequent legislation occurred, however, but an Advisory Committee was appointed in 1927 to report from time to time on the condition of rivers. It has recommended Joint Committees controlling whole lengths of rivers, including tributaries, and at present is considering the problem of amending the Rivers Pollution Prevention Act of 1876, which not only has many weaknesses but is very difficult to enforce. Although Joint Committees, in particular the West Riding of Yorkshire Rivers Board (one of the three Joint Committees of Yorkshire), have greatly improved conditions by going beyond their legal duties and making reports and suggestions to aid sanitary engineers, a great deal of work still remains to be done. Many situations exist which must be remedied before further pollution prevention problems can be considered. Numerous small treatment works must give way to fewer large ones; speedier legal action must be obtainable in dealing with industries causing pollution or about to cause pollution; and country-wide provisions must be made to bring about the satisfactory combination of industrial and domestic sewage handling and treatment.

As an appendix, the author has included descriptions of purification works which have been constructed to meet the requirements of a river authority and of various methods used in the treatment of mill and dye-works' refuse.

A small plant built by the City of Wakefield is described as an example of one of the latest works dealing with sewage on the Sheffield system of bio-aeration, devised by Mr. Haworth. Screens, detritus tanks, aeration channels with paddle wheels, final settling tanks and earthen digestion lagoons are used, with final earthen drying lagoons.

Diagrams and brief descriptions of several trade-refuse purification plants follow, including: (1) a plant using alumino-ferric as a precipitant for

scouring and dye waters and (2) one handling refuse from a mill in which dyeing, bleaching and sizing of cotton goods is carried out, using ferrous sulphate as a precipitant. In the latter, uniform discharge into the settling tank (upward flow type, although ordinary rectangular settling tanks are still most widely used for trade-refuse purification) is brought about by means of a floating arm valve.

Diagrams and photographs are given of two methods of dealing with dye waters when very little space is available. One embodies the use of a sump well, water wheel, small mixing tower and three large settling towers. The effluent is finally strained through wood shavings and is ready to be re-used in the mill. Dye waters and light soap scouring waters have been successfully purified in this fashion. The other method involves the use of an elevated averaging and mixing tank and a sloping, boiler-shell settling tank. The presence of some sludge in the latter at all times is expected to bring about more rapid and complete deposition of solids by the entangling of incoming particles with the settled sludge.

The Chlorination of Sewage at the Seashore near Bathing Beaches

DR. OTTO KLINGBERG AND DR. ERNST SCHROEDTER

Gesundheits-Ingenieur, **53**, 753 (Nov. 22, 1930)

ABSTRACTED BY G. P. EDWARDS

The sewage from the bathing resorts Zoppot and Glettkau-Oliva (combined population 50,000) is treated on sewage farms. The effluent discharged into the sea is slightly turbid, has a stale odor and contains some finely divided matter. About 85 per cent purification, as measured by permanganate consumption, is obtained at the treatment plant. The chlorine number, which is considered a more reliable index, showed 64 per cent purification. Nevertheless, the effluent badly polluted the bathing beaches. In order to have a sufficiently long contact period for the chlorine, the sewage was passed through a settling tank with an hour's detention period before its discharge into the sea. The normal flow is about 80,000 gallons per hour. A chlorine dosage of 6–7 p. p. m. reduced the *B. coli* in the sea near the outfall from about 6000 to 3–50 per cc. Investigation showed that the distribution of the chlorinated sewage was affected by the wind both in a streaming effect and wave motion. On quiet days or with an off-shore wind, as much as 0.7 p. p. m. free chlorine could be detected 500 feet out from the outfall and on both sides along the shore. With a south wind, as much as 1 p. p. m. free chlorine could be detected 650 feet north of the outfall but no free chlorine could be detected

15 feet away on the southern side. With a north wind, a sand bar located under the water about 40 feet from shore considerably lessened the force of the waves and, by a lateral streaming effect, retarded the mixing of chlorinated sewage with sea water. The odor of chlorine could never be detected then.

An hour after chlorination stopped, the sea became as badly polluted as before. An hour and a half after the resumption of chlorination, germicidal action began and, after three hours, the desired disinfection was obtained. Since there were few bathers before eight o'clock in the morning, chlorination could be stopped from nine o'clock in the evening to five o'clock in the morning, producing a saving of about a third in operating cost.

A Report on the Question of the Disinfection of Sewage

PROF. DR. HAYO BRUNS AND W. SCHMIDT

Technisches Gemeindeblatt, **32** (Sept. 20, 1930)

ABSTRACTED BY G. P. EDWARDS

The question of whether or not sewage should be disinfected depends on the purpose of the disinfection and on local conditions. Chlorination to delay the oxygen demand is an entirely different problem than chlorination for the purpose of disinfection.

In 1928, there was a typhoid epidemic in the city of Hagen, in Westphalia. Altogether, there were about seventy cases with at least twenty deaths. Fear that wastes from typhoid carriers and hospitals would cause the epidemic to continue or reappear and the fact that another city was located on the Ruhr River only a mile and a half below the treatment plant made it seem desirable to disinfect the effluent from the treatment works.

The sewage from Hagen flows about $4^1/_2$ miles along the left bank of the Ruhr to the treatment plant. There are a large number of emergency outlets along the course used to by-pass sewage and storm water directly to the Ruhr River during heavy storms. The treatment plant consists of sixteen Imhoff tanks without secondary treatment. Chlorine apparatus had been installed in 1921 for the purpose of disinfecting the clarified effluent in case of an epidemic. On January 28th, the day following the reporting of the first case of typhoid, the chlorinators were put into operation, adding 10 p. p. m. chlorine to the sewage. Bacteriological analyses, including total counts on gelatine and the determination of *B. coli*, were made daily. Tests for free chlorine were also made. The chlorinator was placed 1900 feet from the Ruhr and samples were collected about 1400 feet

below the chlorinator. The time of flow from the chlorinator to the sampling point was about 9 minutes.

During February, the number of bacteria were reduced from 1.5–3 million to 0.5–1.5 million. On March 2nd, the chlorine dosage was increased to 15 p. p. m. and the contact period was also lengthened. Under this treatment, the number of bacteria decreased from 2–4 million to about 200,000. The *B. coli* also decreased from about 20,000 to 1000 per cc. On March 16th, the chlorine dosage was increased to 20 p. p. m. and the number of organisms decreased to 10,000–30,000 or about 99 per cent. The *B. coli* decreased about the same amount.

Fairly heavy rains fell during the first three weeks of the experiment and the emergency outlets for by-passing sewage and storm water directly to the river were frequently used. It is doubtful whether chlorination of the plant effluent was worth while during this time, since often only a small part of the total flow was clarified. It was impossible to chlorinate at each outlet unless storage tanks were built, because the distance from the sewer to the river is only about 33 feet in many places. The cost of tanks alone for the city of Hagen would be about $250,000. The cost of the experiment, including 26,970 pounds of chlorine, was at least $3670.

It is doubtful whether continuous chlorination of sewage is worth while, considering the cost and the results obtained. It is better to disinfect the wastes before they enter the sewerage system. All drinking water suspected in any way should be chlorinated for the entire period of the epidemic.

Modern Sewage Disposal and Hygienics

BY S. H. ADAMS*

REVIEWED BY F. W. MOHLMAN

This book of 473 pages is quite unique in style and contents. It could hardly be recommended as a reference or textbook because of the preponderance of historical material, and rather unsatisfactory treatment of the present status of the science of sewage treatment. The greatest value of the book lies in the remarkably comprehensive review of the development of sewage treatment in England and the complete résumé of the Ministry of Health requirements for sewage effluents and plant capacities.

American readers will be grateful for the inclusion of material from many British reports not ordinarily available, or forgotten during the rush of progress in sewage treatment during the past decade. The author's account of this past work is very readable; in fact, the most attractive feature of the book is its narrative style and profuse illustrations.

* *Published by Spon and Chamberlain, 120 Liberty Street, New York.*

The book is not so attractive from the standpoint of accuracy of composition. It is poorly bound and the proof-reading is bad. For example, on page 268, "dry weather" sludge is shown with zero moisture; obviously, this should be "dry weight." On page 302, it is stated that CO was removed from sludge gas by lime; CO_2 was meant. There are other minor errors of this sort.

The first fifty pages include a detailed sanitary history of London, going back to the year 1286. This section digresses widely from considerations of sewerage and sewage disposal, but the caption "in the paths of hygeia" may explain this digression.

Later chapters are more closely concerned with sewage disposal. The Ministry of Health requirements and standards of purity of the various River Boards occupy 100 pages. The normal standard for effluents from biological treatment, as set by the Royal Commission, has stood as a reasonable requirement through many years of development: "An effluent should contain not more than 3 parts per 100,000 of suspended matter. An effluent with the suspended matter included must not take up at 65° F. (18.3° C.) more than 2 parts per 100,000 of dissolved oxygen in 5 days."

Toward the end of the book a chapter is devoted to the work of the Lawrence Experiment Station, during its 40 years of uninterrupted experiments under Harry W. Clark. The author states that "a résumé of the work done at this station and its findings is, in effect, a history of the growth of the science of biological sewage purification over that period."

The final chapter is a chronological list of events affecting sanitary and social conditions and progress in their relation to public health, from 600 B. C. to 1929 A. D. The final plate, from Marcus Aurelius, is well suited to bring the proper humility of spirit to the reader or the reviewer: "Short lived are both the praiser and the praised, and the rememberer and the remembered; and all this in a nook of this part of the world; and not even here do all agree, no, not anyone with himself."

Abstracts of Papers Presented at the Fourth Annual Conference of the Maryland Water and Sewerage Association

May, 1930

ABSTRACTED BY H. GLADYS SWOPE

Determination of Oxygen Demand by the Direct Oxygen Method. BY E. C. CROMWELL. A comparison is made of the dilution method and the direct (Sierp) method for determining the biochemical oxygen demand.

The author tried several dilution waters, using 500 p. p. m. $NaHCO_3$, 100 p. p. m. $NaHCO_3$, 100 p. p. m. $KHCO_3$ and distilled water. After the salt was added, the carboy of water was thoroughly shaken and set aside for two weeks at 20° C. The initial dissolved oxygen was determined.

In the direct oxygen method, the bottles were shaken every two and one-half hours. Readings were made just before shaking, which eliminated the necessity of making initial and final dissolved oxygen determinations for corrections.

Fifteen 5-day and several 20-day tests were made. The average of six consecutive 5-day B. O. D.'s showed that the dilution method, when distilled water was used, was lower than the Sierp method and, when distilled water containing 500 p. p. m. $NaHCO_3$ was used, higher. In a comparison (3 tests) of the dilution method, using water containing 100 p. p. m. $NaHCO_3$, 100 p. p. m. $KHCO_3$ and distilled water with the Sierp method, the dilution method gave lower results in all cases. Demands were lower with $KHCO_3$ and higher with $NaHCO_3$ than with the distilled water.

In a study of the two methods over a period of 20 days, discordant results were found with the dilution method.

Sewage Treatment Problems at Hagerstown, Md. BY W. C. SLEE AND L. R. VORIS. The Hagerstown sewage treatment plant was built in 1925 and designed for 3 m. g. d. when complete. At that time only one tank was equipped for aeration (capacity 800,000 gallons)—combination of air diffusion through porous plates and a C. Lee Peck mechanical aerator. In 1930 the plant was re-designed to take care of the entire flow of 2.2 m. g. d. It now includes a bar screen; a self-cleaning fine screen; grit chambers; two aeration tanks, capacity 1.1 m. g. d. each (based on a six-hour detention period); and two final settling tanks with detention period of 1.5 hours. Lime is added to sludge in a mixing tank before running it onto sand beds. The sludge, when dry, contains 60 per cent moisture and is used for fertilizer.

Experiments were run on an Electro-Dialyzer for sewage treatment. The raw sewage was run through the dialyzer without chemical treatment, with the addition of 3.3 p. p. m. of chlorine and carrying a residual of 0.2 p. p. m., with the addition of 400 pounds of lime per million gallons, and with 400 pounds of lime plus 200 pounds of copperas per m. g. Chemical analyses were made before and after treatment. No conclusions are given.

Separate sludge digestion studies were made during 1928. The results showed that the volatile matter decreased and moisture increased.

Regular Supervision of Institutional Water and Sewage Treatment Plants in Maryland. BY A. W. BLOHM. Because of the poor condition

of waterworks and sewage plants in institutions the State Department of Health now makes regular inspections, the institutions paying a nominal sum for this supervision.

English and German Practice in Sewage Treatment. BY C. E. KEEFER. The author discusses sewage treatment abroad under the following headings: Screens, Grit and Oil Chambers, Settling Tanks, Trickling Filters, Activated Sludge, Sludge Dewatering and Sludge Disposal.

The Europeans lay more stress on coarse screens than we, due to their concentrated sewage. Wing screens are used at Bradford, England, consisting of a series of bars radiating from a central shaft. Fine screens are used for removing sulphur bacteria from settled sewage. At Hamburg, Brunotte screens are used. These are made of structural steel framework, over the front and back of which moves a group of members, provided with long narrow openings through which the sewage flows. Geiger screens (an inclined rack cleaned by brushes) are also used in Germany. At Essen-Rellinghausen a drum screen is used for screening activated sludge.

Grit chambers are much the same as in this country. More stress is laid on oil removal and skimming devices abroad than here.

Various types of settling tanks are used. Long detention periods are employed in England (12 hours) and short ones in Germany (2–3 hours). Sludge is removed by hand in England and mechanically (generally by the use of squeegees) in Germany. At Karnap, Germany, sludge is removed while settling tanks are operating.

Trickling filters and activated-sludge installations are much the same abroad as here. A combination of diffused air with mechanical aeration is used in Germany. Contact aerators are still being built in the Ruhr district. Separate digestion is used at Bath and Birmingham, England.

In Germany sludge gas is used for heating tanks and sold at Stuttgart and Nurnberg.

Abstracts of Papers Presented at the Twelfth Texas Water Works Short School

January, 1930

ABSTRACTED BY H. GLADYS SWOPE

Improvements in Waterworks and Sanitary Sewer Systems of the City of Dallas. BY JOHN M. FOUTS. For many years the sewage of Dallas was discharged into the Trinity River. In 1910 a stream anti-pollution law was passed, which resulted (in 1917) in a system of interceptor mains and a disposal plant. Twelve Imhoff tanks with a capacity of 12

m. g. d. were installed. This gave only partial treatment. In 1924 the capacity of the plant was increased. In 1927 a bond issue was passed for building mains and lateral interceptors. Plans are under way for a complete treatment plant.

Progress in Sewage Disposal. BY V. M. EHLERS. This paper was published in THIS JOURNAL, **II,** 105–110 (January, 1930).

The San Antonio Sewage Treatment Works. BY H. R. F. HELLAND. From 1901–1928 the sewage was handled by broad irrigation. In 1928, plans were laid for the construction of a sewage treatment plant. Prior to the design, flow measurements and analyses of sewage were made for a period of 10 months. The average flow was 16.4 m. g. d. with a maximum of 28.4 m. g. d. Suspended solids averaged 260 p. p. m., volatile matter, 68.4 per cent and ash, 31.6 per cent, giving 0.163 pounds per capita per day of dry solids. The present population is assumed to be 285,000, with 220,000 connected to the sewerage system. The plant will be designed to handle 30 m. g. d.

The treatment works comprise a screen house, grit chambers, preliminary sedimentation tanks, aeration tanks, final clarification tanks, digestion tanks, sludge lagoons, pump station and laboratory.

The screenings are to be burned in an incinerator built inside the screen house, using gas from the digestion tanks as fuel for the incinerator. The grit chamber has three channels, designed for a velocity of 1 foot per second. The primary settling tanks are 60 feet square, with an average water depth of 11 feet, and are designed for 30-minute settling periods. Aeration is provided in the inlet to these tanks. After preliminary settling, sewage is mixed with 20 per cent returned sludge; it then goes to aeration tanks which are designed for 5 hours aeration, using 1.5 cu. ft. of air per gallon of sewage. The final clarification tanks are designed for a two-hour settling period.

The sludge digestion tanks are fitted with gas-collection domes.

Grades for Sanitary Sewers. BY O. K. HOBBS. The paper shows that flat grades for sanitary sewers are preferable. During the year 1929 there were 24 sewer stops in a total of 66.7 miles laid by the city of Abilene and all of these occurred in 6-inch pipe in which the grade was 0.536 per cent; the grades for the other sizes of pipe were: 8-inch—0.432 per cent, 10-inch—0.308 per cent, 12-inch—0.280 per cent, 15-inch—0.188 per cent, 18-inch—0.175 per cent and 24-inch—0.100 per cent.

The Effect of Gases on Growth of Bacteria. BY R. G. UPTON. This report is a continuation and validation of the work published in the "Eleventh Annual Report of the Texas Water Works Short School" (1929). It was shown that the total numbers of bacteria, on plain agar, were increased to a noticeable degree but that H_2S-forming colonies and other anaerobes were little affected when the sewer gases were pumped out of a

digestion tank by production of a partial vacuum. Sewer gases are not toxic to the bacteria which accomplish digestion of sludge.

Lagooning Sludge. BY EDGAR WHEDBEE. In 1926 the sludge at Dallas was lagooned, due to insufficient drying bed capacity during the rainy season. The lagoon was used for the skimmings and excess sludge during 1926 and, as no odors were noticed and costs could be cut down by lagooning, all of the sludge has been taken care of in this way since 1927.

Some Observations on the Treatment of Creamery Wastes. BY MAX LEVINE. Milk wastes are detrimental to the functioning of a treatment plant due to the lactose which, on fermentation, becomes acid (in septic tanks). Various experiments showed that treatment of these wastes on trickling filters using coarse cinders or lath and a short dosing period ($7^1/_2$ minutes) reduced the B. O. D. from 1100 p. p. m. to 95 p. p. m. and produced a stable effluent.

Advantages of Sludge Circulation and Vacuum Degasification as Applied at the Cleburne Plant. BY CLYDE C. HAYES. The plant consists of a grit chamber, Imhoff tank with central gas vent, dosing chamber with Miller syphon, sprinkling filters and a separate sludge digestion tank. Since recirculation and degasification have been carried on in the Imhoff tank there have been no difficulties such as inadequate sludge-digestion capacity, foaming or odor troubles.

Financing Sewer Connections and Plumbing Installations. BY M. R. DIGGS. This paper discusses privately-owned sewerage systems and sewage treatment plants, and how to make them pay.

Financing Home Sanitary Sewer Facilities on the Easy Payment Plan. A questionnaire was sent out to each state in the U. S. by a committee of the A. P. H. A. on the above subject. Thirty states replied and six answered affirmatively. Where the state laws did not make such provisions it was concluded that laws for payment on the installment plan should be encouraged.

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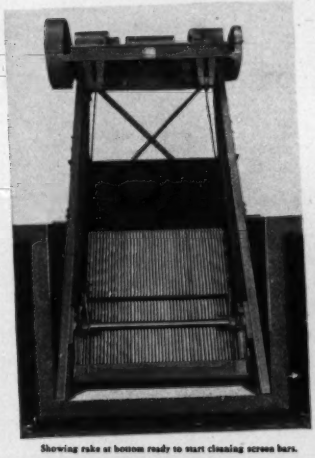

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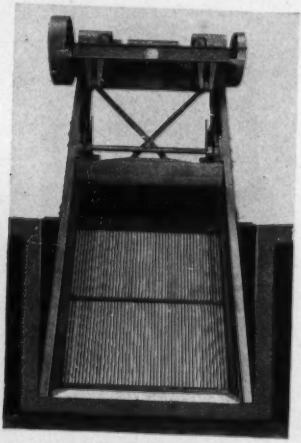

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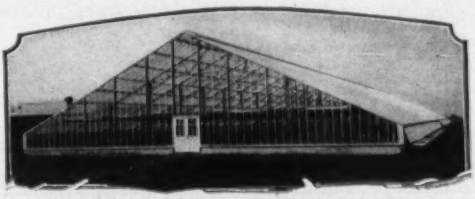

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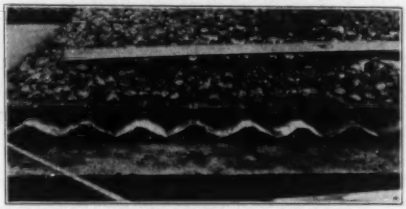

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